Biological Aspects, Catch and Length Distribution of African Catfish, *Clarias gariepinus* and Common Carp, *Cyprinus Carpio* in in Lake Lugo, South Wollo, Ethiopia

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ABSTRACT

Determining biological parameters such as length to weight relationship, sex ratio and size at first maturity of threatened fishes give good information on their growth performance and help manage and conserve fish populations in their natural water bodies. In this study, some biological parameters were reported for *Clarias gariepinus* and *Cyprinus carpio*. Samples were taken at monthly intervals from October 2013 to September 2017 in Lake Lugo, South Wollo, Ethiopia. The objective of the study was to determine length to weight relationships, length class frequency, sex ratio and size at first maturity of the fishes. Total length (TL) of the species was measured to the nearest 0.1 cm and total body weight (TW) to the nearest 1 g. The physico-chemical parameters were also measured: transparency by using secchi disk, conductivity by Wagtach International conductivity meter and pH by pH meter. The results showed that the parameters were within the permissible limits except the pH level at Gedam Sefar sampling site. A total of 672 fish specimens were collected. Length (cm) to weight (g) relationship for *C. gariepinus* was sketched as: $TW = 0.015TL^{\mathbf{2.8}}$, n = 81, $r^2 = 0.901$ and for *C. carpio* as: $TW = 0.018TL^{\mathbf{2.85}}$, n = 591, $r^2 = 0.926$, which, in both cases, showed a curvilinear relationship, signifying the fishes followed negative allometric growth. The sex ratio between males to females showed significant difference (*C. gariepinus*: $\chi^2 = 4.46$, $P<0.05$; *C. carpio*: $\chi^2 = 12.0$, $P<0.05$). Size at first sexual maturity (L_{50}) for *C. gariepinus* was 31.7 cm for females and 31.1 cm for males, while L_{50} for *C. carpio* was 19.2 cm for females and 19.3 cm for males.

Keywords: Length-weight relationship, Sex ratio, Size at first maturity, Size groups
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INTRODUCTION

The water bodies of Ethiopia represent 7334 km^2 of major lakes, 275 km^2 of small water bodies (reservoirs) and 7185 km of rivers) (FAO, 2015). Until about 50 years ago, the contribution of fisheries to the Ethiopian economy was insignificant because of abundant land-based resources and a sparse population density. Ever since the 1940s and 50s, however, the rapid population growth resulted in a shortage of cultivated land and depletion of land resources and forced people to look for other occupations and sources of food at a subsistence level from water resources (Alayu Yalew *et al*., 2015). Approximately 45 thousand fishers were employed in the primary sector with 30% employed fulltime, in addition to nearly 700 people engaged in aquaculture. The current total fish production potential of the country is estimated at about 52 thousand tons annually for the main water bodies, and the production increased from 29 thousand tons in 2012 to around 38 thousand tons very recently (FAO, 2014). The Ethiopian inland water resource faces multifaceted challenges including severe fishing pressure, destructive fishing methods, deteriorating water quality because of land-based activities and lack of scientific information for proper fish resource management (Gashaw Tesfay, 2016).

Amhara Region has high fish production potential from major lakes like Lake Tana, and small lakes like Lugo and Ardibo. Moreover, the region has a considerable fish production potential from rivers like river Shinfa, Sanja, Ayima, Gendwuha and others (Dereje Tewabe, 2008). Lake Lugo in Wollo of northeastern Ethiopia is among the most severely affected in Ethiopia because of drought and famine over the last decade.

The Lake was stocked with tilapia from a crater lake near Addis Abeba (probably Lake Hora), in 1978 by the Fisheries Department of the Ministry of Agriculture, to provide food for the community. The harvest by a newly established gillnet fishery has increased to 200 tons per year (84 kg/ha). However, mass fish mortality occurred in November and December because of cool weather and rains. As a result, 1 m wide accumulation of dead fish along the wind ward (west) shore of the lake created a nuisance as well as a significant loss of fishes (Elizabeth Kebede and William, 1992). Also, negative anthropogenic activities such as land use change (growing annual and perennial crops, land fill system along the shore line) destroyed the fish habitat and impacted fish production (Dereje Tewabe, 2015). Traditional practices of the surrounding communities co-existed in harmony for centuries.

At Lake Lugo, four fish species namely Nile tilapia (*Oreochromis niloticus*), catfish (*Clarias gariepinus*), common carp (*Cyprinus carpio*) and garra (*Garra dembecha*) are found. *Garra* sp. has no economic value in the lake and fishers are not interested in it. The current study was focused on two of the four fish species, i.e., catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*) because of the lack of information on their length-weight relationships, sex ratios, and size at maturity. Currently, management plan that ensures the conservation and sustainable use of the lake resources is lacking. Various researchers have studied the biology of fishes at different water bodies in Ethiopia. Lake Lugo is not one of them. Therefore, the present study was intended to generate crucial information on length-weight relationships, sex ratio, and maturity size of fishes and physico - chemical parameters (transparency, temperature, conductivity and pH) of the water in the lake. The results provide baseline information for fishery managers and scientists who are interested in the lake.

MATERIALS AND METHODS

Description of the study area

Lake Lugo, 30 km away from Dessie, is found in Tehulidre Woreda, South Wollo administrative zone, Northeastern Ethiopia (Figure 1). It lies at 11°15′ N latitude, 39°57′ E longitude and at an altitude of 2,030 m above sea level (Baxter, 1970). The mean maximum depth of the Lake is 77 m and the minimum is 30 m (Dereje Tewabe *et al.,* 2015). Ankerkha River is the only river that enters at the southern corner of the lake, now permanently dry because of irrigation schemes upstream. Fishing activities used to be done using monofilament gillnet stretched mesh size of less than 8 cm, hook and line, traditional boat (Tankua).

Site selection and sampling

Three sample sites, Gedam Sefar, Pelagic and Ankerkha River mouth were selected purposively based on vegetation cover, human and animal interference intensity. Gedam Sefar site is covered with denser vegetation, Ankerkha River mouth is where Ankerkha River meets Lake Lugo and Pelagic is open water. Ankerkha River is the principal source of sediment in Lake Lugo. During the dry season, the water level of Ankerkha River water level decreases, sometimes completely dries.

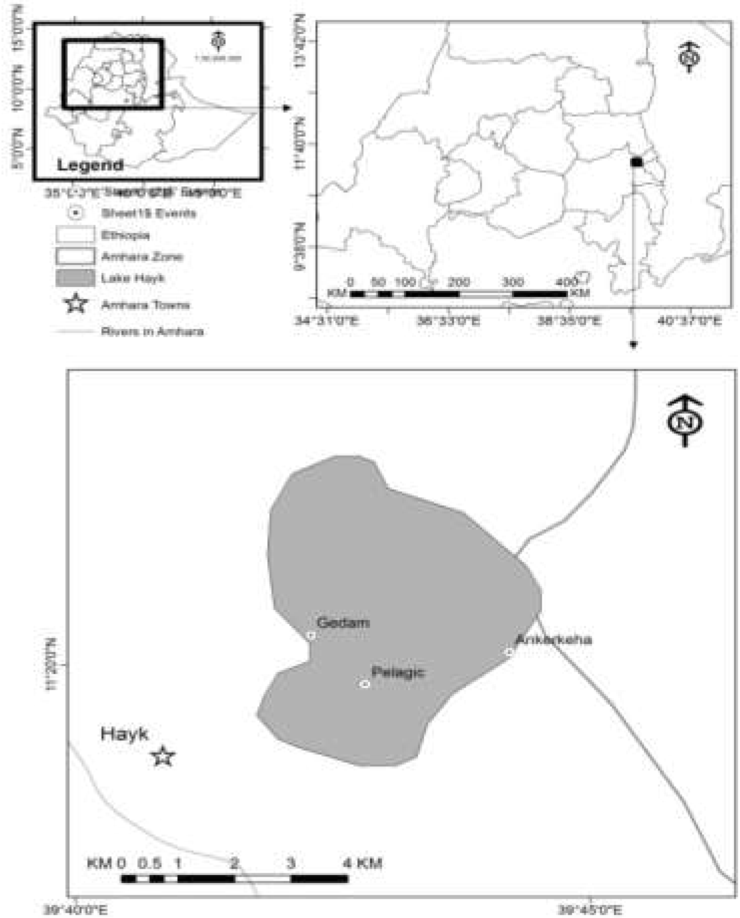


Figure 1. Map of the study lake and sampling sites.

In this study, the Pelagic or open water is used as reference point. It is the deepest part of the lake. In each sampling site, fish specimens were sampled every month from October 2013 to September 2017. Gillnets of various stretched mesh sizes, i.e., 6, 8, 10 and 12 cm, were used to catch fish specimens. The nets were set at 5:00 PM late afternoon and retrieved at 7:00 AM early morning. Immediately after capture, the total length (TL) of each fish was measured in centimeters using measuring board and the total body weight (TW) was measured in grams to the nearest 0.1 gram using electronic weighing balance (AC power supply: 50 hz, Battery: 6v. DC/4AH). The degree of sexual maturity and sex of each specimen was determined by inspection of the gonads in fresh individuals using maturity scale (Holden and Raitt, 1974). The physico-chemical parameters such as transparency, temperature and conductivity and pH of the lake were measured by using Secchi disk, Wagtech International conductivity meter and pH meter, respectively.

Data analysis

Length to weight relationships was estimated employing the equation of power function (Bagenal and Tesch, 1978)

$$TW = aTL^b$$

Where, TW = Total weight (g), TL = Total length (cm), a = Intercept of the regression line and b = Slope of the regression line.

For each species, the parameters a, b, and r^2 were estimated by regression analysis. The “b” value for each species was tested by t-test.

Sex ratio

Sex ratio was determined by the total number of captured females divided by the total number of captured males. Chi-square test was employed to test if sex ratio varied from 1:1; the samples were collected in each month for various size classes. The sex ratio was determined in breeding and offseason separately and finally in combined form.

Length at first maturity (L_{50})

The length at first maturity L_{50} was estimated by classifying the gonads as immature (stage I and II) and mature form (stage III-V). The relationship between the percentages of mature fish (P) per length class (X) was described by logistic curve and L_{50} was estimated according to Gunderson *et al*. (1980).

$$P_X = \frac{1}{(1+\exp(bx+a))}$$

Where, P is the proportion of mature fish at length class x: a and b are model parameters (where, a = intercept, b = slope of logistic regression. L_{50} was then derived from the relationship of "a" and "b".

$$TL = -\frac{a}{b}$$ (Sparre and Venema, 1998).

Descriptive and inferential statistics were used (Excel window 10 and SPSS statistical software version 22). All the statistical analyses were considered at significance level of 5%.

RESULTS AND DISCUSSION

Physico - chemical parameters

The physico-chemical (abiotic) parameters were measured at all sites in the study area. The physico - chemical parameters such as transparency, temperature, conductivity and pH of water were compared among sampling sites (Table 1). At Ankerkha river mouth sampling site, minimum conductivity was 360.5±92.6, transparency was 2.8, and temperature was 22.1±2.12; at the Pelagic sample site, the minimum pH recorded was 8.9±0.57, the maximum conductivity was 403.67±16.25 and transparency was 3.5. Gedam Sefar sampling site had a maximum pH value of 9.1±1.34 and temperature of 23.9±0.49 (Table 1).

According to Hamed *et al*. (2013), the pH value from 7.9 to 9 is considered moderately alkaline, above which is considered highly alkaline. It is probably due to the effect of direct point and non-point source of pollution disposed near to their location. Alkalinity at Gedam Sefar site was relatively higher than the other sites. It is probably due to the nature of the watershed topography which depended on many variables and mixtures of different drainage water coming from agriculture and waste water. For fish culture, the optimum permissible limits of pH is 6.5 - 9.0, conductivity is 50 – 1500 µs/cm (Boyd, 1979), and temperature is 20-30 °C (Hamed *et al*., 2013).

Table 1. Mean and standard deviations of physic - chemical parameters of Lake Lugo at each sampling sites (temperature (^{0}c), transparency (m), Conductivity (µs/cm)).

Sample sites	pH	Conductivity	Temperature	Transparency
Gedam Sefar	9.1±1.34	401.0±41.01	23.9±0.49	3.0
Pelagic	8.9±0.57	403.7±16.25	22.8±0.97	3.5
Ankerkha	9.0±0.08	360.5±92.63	22.1±2.12	2.8
Standard	6.5-9.0	50-1500	20-30	30-80
References	Boyd (1979)	Boyd (1979)	Boyd (1979)	Hamed *et al*. (2013)

Length-weight relationships

A total of 672 fish specimens were collected during the study period. Because of overfishing, numbers were low, i.e., 81 *C. gariepinus* and 591 *C. carpio* fish were found. Mean total length of *C. gariepinus* fish was 39.71±11.68 cm (range: 17.1 and 89.5), and total weight was 644±805.03 g (range: 55 to 6515); for *C. carpio* fish, mean total length was 29.2±9.75 cm (range: 7.8 to 60.5) and the total weight was 377.55±348.521 g (range: 20 to 1545). The relationships between total length and total weight of *C. gariepinus* and *C. carpio* were curvilinear and statistically significant ($p < 0.05$) (Figure 2). In the present study, *C. gariepinus* and *C. carpio* exhibited negative allometric growth (Figure 2). Fishes may have "b" value greater or less than 3, a condition of allometric growth (Bagenal and Tesch, 1978). Length to weight relationships followed negative allometric growth, i.e., b = 2.801 for *C. gariepinus* and b = 2.853 for *C. carpio*.

Several authors have reported allometric growth for *C. gariepinus* and *C. carpio* from various other water bodies. The value of "b'' for the combined data of both sexes in the present study is comparable to the value of b calculated for the same species of *C. gariepinus* in the head of Blue Nile River, which was negative allometric growth, i.e., b = 2.4 (Mohammed Omer, 2010) and b=2.67 in Lake Tana (Dereje Tewabe, 2014). In Amerti reservoir, *C. carpio* resulted in b = 2.923 (Mathewos Hailu, 2013) and in Lake Ziway b = 2.93 (Lemma Abera *et al.,* 2015).

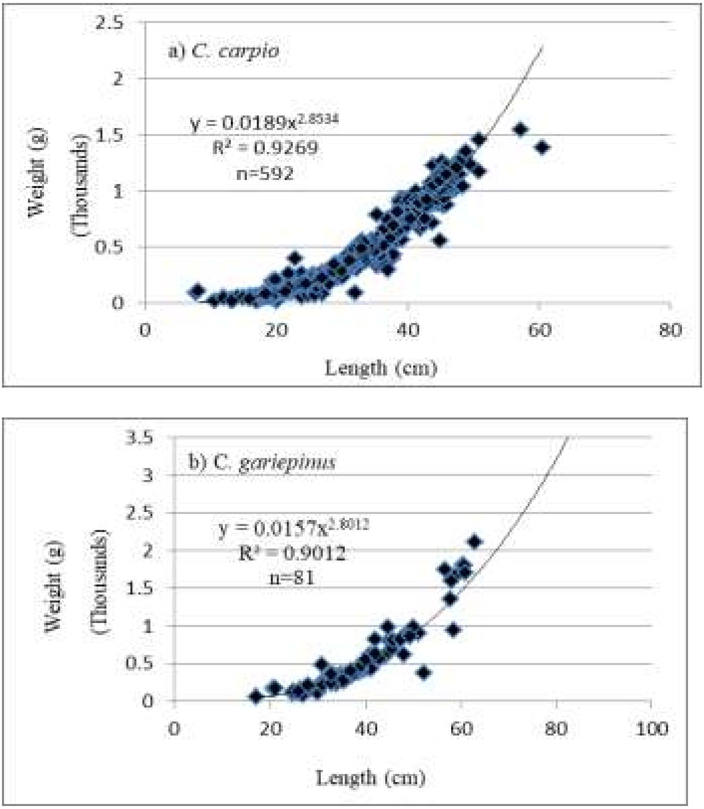


Figure 2. Length-weight relationship of C. *gariepinus* and *C. carpio* at Lake Lugo

The parameters of the LWR might be affected by various factors including season, sex, length of caught specimens, population density, sexual maturity, age, habitat, stomach fullness, food quality or quantity, preservation techniques, fish health or environmental conditions (Cox and Hinch, 1997; Lemma Abera *et al.*, 2015). The variation of the magnitude of "*b"* values may also depend primarily on the shape and fatness of the species as well as physical factors such as temperature, salinity, food, stage of maturity, habitat, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Bagenal and Tesch, 1978; Pauly, 1984; Sparre and Venema, 1992; Wootten, 1998; Froese, 2006; Sarkar *et al.,* 2013). The coefficient of determination (r^2) for length-weight relationships was high for all fish species which indicated that the length increased with increase in weight of the fish (Tah *et al*., 2012; Koffi *et al*., 2014). Similar results were reported before from different fish species and water bodies.

Length frequency distributions of *C. gariepinus* and *C. carpio* fish species

C. gariepinus had a total mean length of 39.71 ±11.68 (range: 17.1 to 89.5 cm) and *C. carpio* had 29.67±9.73 (range: 7.8 to 60.5 cm) (± is standard deviation). More of *C. carpio* fishes were found in size classes 19-23 and 23-27 cm, and *C. gariepinus* in 31-35 and 35-39 cm sizes (Figure 3).

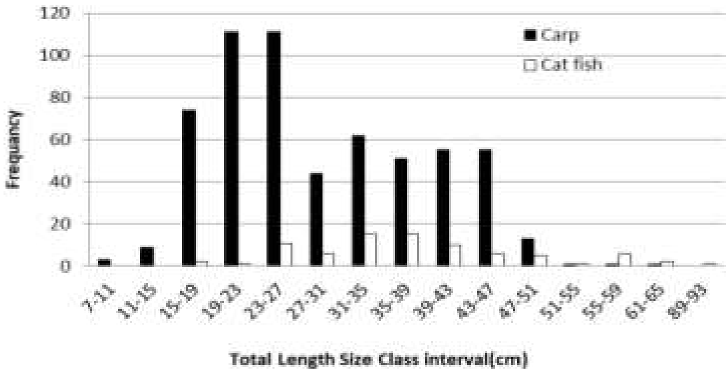


Figure 3. The length frequency distributions of *C. gariepinus* and *C. carpio* in Lake Lugo (data from 2013-2017).

Spatial distribution of fishes

Gillnet selectivity has been compared among 6 cm, 8 cm,10 cm and 12 cm stretched mesh sizes. Of those, 6 cm mesh size has caught 35.4% of the total catch by number (Table 2). This implies that such fishing pressure has put negative effect on Lake Lugo and as a result small sized fishes are becoming more abundant than table sized ones.

Table 2. Gillnet selectivity of 6 cm, 8 cm, 10 cm and 12 cm stretched mesh sizes.

Gillnet	Number of captured fishes	Number (%)
6	238	35.4
8	121	18.0
10	146	21.7
12	167	24.9

Table 3 shows spatial distribution of fish populations in Lake Lugo across three sampling sites. The spatial distribution of the fish population showed that the two species may not necessarily correlate positively. *C. carpio* fish were more abundant at Ankerkha River mouth sampling site, because the river mouth had good substrates. In contrast, the population of *C. gariepinus* was low. The proportion of C. *gariepinus* collected was 12% and *C. carpio* was 88%. The abundance of fishes captured declined steadily from year to year due to overfishing (Figure 4).

Table 3. Spatial distribution of *C. gariepinus* and *C. carpio* fish population at three sampling sites of the study lake.

Sampling sites	*C. gariepinus*		*C. carpio*	
	Number	%	Number	%
Gedam Sefar	57	70.37	218	36.9
Pelagic	14	17.28	143	34.2
Ankerkha	10	12.35	230	38.9
Subtotal	81	100	591	100

Figure 5 shows the proportions of C. *gariepinus* and *C. carpio* fishes captured in the *Bega* or dry season (October-January), in the short rains (February-May) and in the long rains (June-September). Over the years, *C. carpio* catches steadily declined in the long rains and oscillated in the Bega and the short rains. C. *gariepinus* was high in short rains, medium in the Bega and low in the long rains.

Sex ratio

The sex ratio between males to females showed significant difference (*C. gariepinus*: $\chi^2 = 4.46$, $P<0.05$; *C. carpio*: $\chi^2 = 12.0$, $P<0.05$) (Table 4). Both species in Lake Lugo were not equally distributed. The sex ratios of females and males' *C. gariepinus* and *C. carpio* were different from the 1:1 ratio in the offseason (September-April), but not in the breeding season (May-August) (Table 4).

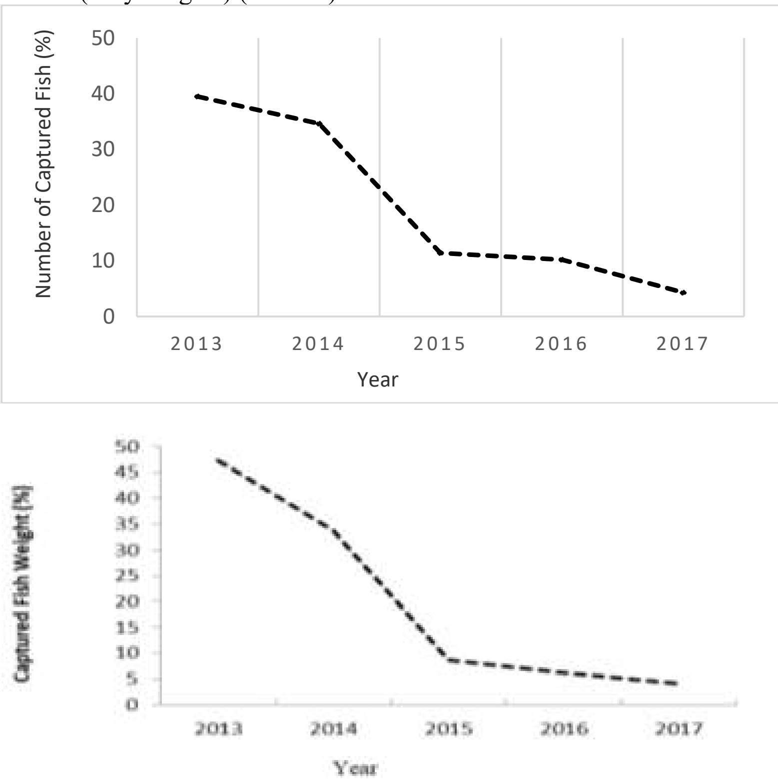
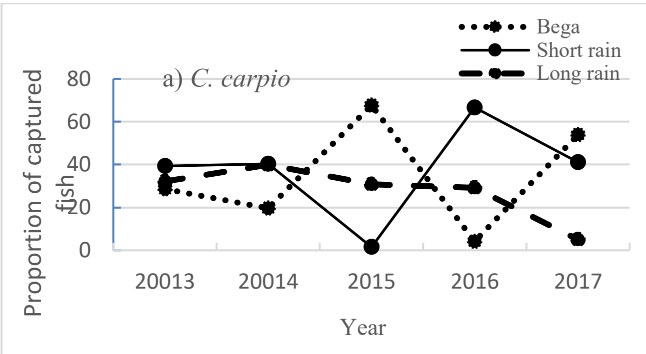


Figure 4. Fish catch trends in Lake Lugo from 2013 to 2017 the study periods

The overall sex-ratio (F: M) was 1.61:1 for *C. gariepinus* and 0.66:1 for *C. carpio*, a deviation from the expected 1:1 in favor of female *C. gariepinus* and male *C. carpio.* In contrast, in Amerti reservoir, the sex ratio of *C. carpio* between females and males was 1:1.15, which did not differ significantly from 1:1 (χ^2 = 2.33; P = 0.126) (Mathewos Hailu, 2013). Despite the lack of concrete evidence for biased sex ratio for the present study, it may be caused by sexual segregation during spawning, behavioral differences between sexes, gear type used and differences in fishing site (Demeke Admassu, 1994). Growth rates of sexes vary considerably; females generally grow bigger than males. Other biological mechanisms such as differential mortality rates or differential migratory patterns between the male and female sexes may also cause unequal sex ratios (Dereje Tewabe, 2014).

Table 4. Sex ratio estimation of fish species at Lake Lugo.

Species	Season	Females	Males	F: M	χ^2- Chi-square
C.gariepinus	Breeding	17	18	0.944:1	0.03^{ns}
	Offseason	14	32	0.4375:1	7.04*
	Total	31	50	1.61:1	4.46*
C. carpio	Breeding	83	102	0.814:1	1.95^{ns}
	Offseason	153	253	0.605:1	24.63*
	Total	236	355	0.66:1	12.00*



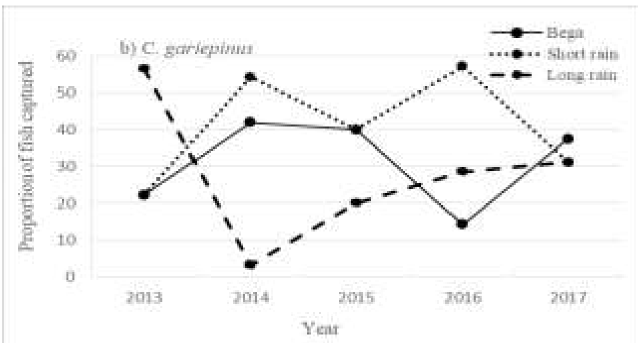


Figure 5. The proportion of captured *C. carpio* and C. *gariepinus* at Lake Lugo

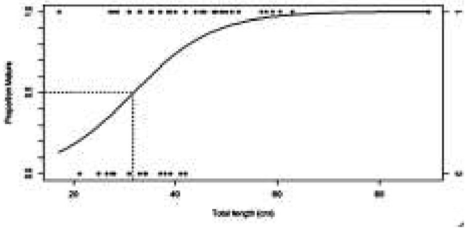
Length at first maturity (L_{50})

The total length at which 50% of the *C. gariepinus* reached maturity using the proportion equation were 31.7 cm for females and 31.05 cm for males; for *C. carpio* it was 19.2 cm for females and 19.3 cm for males. The L_{50} value of the fishes obtained in this study was lower than the results reported by different scholars and researchers (Table 5). The relationship between the percentages of mature (p) females and males of *C. gariepinus* and *C. carpio* fish per length class (X) were described by logistic curves (Figure 6).

Length at maturity in many fish species depends on demographic conditions, genes and the environment, changes in Lake water level and associated factors such as poor condition or overfishing; poor conditions result in small sized fish (Lowe- McConnell, 1958). Fishing pressure is a major factor causing reduced length at maturity (Cowx, 1990). Therefore, the length at first maturity in Lake Lugo was smaller than those in Lake Tana and Fincha Reservoir. Abundance and seasonal availability of food, temperature, photoperiod, dissolved oxygen and other environmental factors, such as overfishing, changes in Lake water level and poor condition could reduce length at 50% maturity (Babiker and Ibrahim, 1979; Bwanika *et al.,* 2004). Furthermore, predation and competition could contribute for the small sized fish at first maturity (Bwanika *et al.,* 2004). During the fishing process, many fish die in the process and this condition signals the production of smaller fish with available resources to compensate for the losses incurred and to perpetuate their own offspring.

Table 5. Length at maturity (L_{50}) of fish species as determined by different authors at different times.

Fish species	Present study (Lugo		Dereje Tewabe (2014) (Lake Tana)		Fasil Degfu *et al*. (2012) (Fincha)		Endalh Mekonnen *et al.*, (2018) (Ardibo)	
	F	M	F	M	F	M	F	M
C. garipenius	31.7	31.1	57.7	43.2	----	-----	---	---
C. carpio	19.2	19.3	----	-----	37.5	24.5	19.23	19.24



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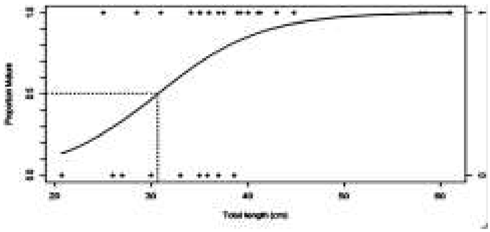

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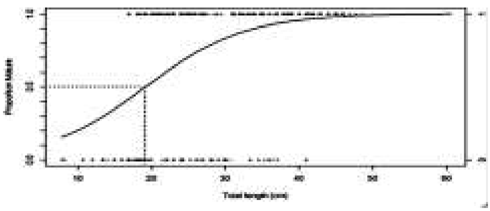

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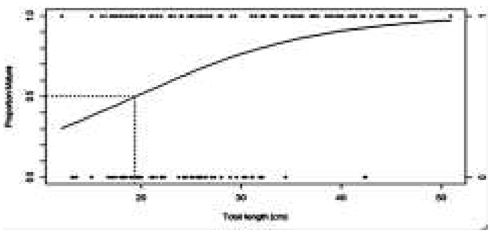

D

Figure 6. Size of fish species at first maturity (L_{50}) of *C. gariepinus* (Females=A, Males=B) and *C. carpio* (Males= C, Females =D).

CONCLUSION

In Lake Lugo, the length-weight relationships of fishes in our study gave a curvilinear pattern that was statistically significant negative allometric growth curve. At maturity, males of *C. gariepinus* were smaller than females; in contrast, females of *C. carpio* were smaller than males. Based on percentage composition, *C. carpio* is relatively the most dominant fish in Lake Lugo, which contributed to 88 % of the total catch. The sex ratio of *C. gariepinus* and *C. carpio* were different from the expected 1:1 ratio. More of *C. carpio* fishes were found in size classes 19-23 and 23-27 cm, and *C. gariepinus* in 31-35 and 35-39 cm sizes.

Based on our fish stock monitoring exploratory research program, it was observed that the fishermen continuously fished throughout the year including the reproductive season by using monofilament gillnets that had mesh sizes less than 8 cm which catch fish before they produce eggs to replenish the stock. The size at first maturity of both species in Lake Lugo indicated that the fish population was overfished, highly stressed and over exploited. Lake Lugo is known for its wide biodiversity of flora and fauna, but the ecology of the lake and its catchment and its natural resources are threatened because of fluctuations in water-levels that is aggravated by human activity.

The fish resources are threatened because the fish breeding ground is being destroyed by livestock grazing and crop production as a result of rural population growth (intensive irrigated farming, land redistribution, deforestation, absence of effective lake management system and human activities particularly overfishing by individual fishers, and increasing multipurpose use of the lake waters.

The unregulated open access resource use and uncoordinated water resources development activities would cause degradation of fish resources in particular and other natural resources in general.

RECOMMENDATIONS

In order to have a better knowledge of the fish populations detailed studies and investigations are required on maximum sustainable yield and efforts applied for the maximum sustainable yield of fish species in Lake Lugo. We recommend the fishermen have to use a fishing gear greater than 8 cm stretched mesh size for sustainable utilization of the stock in Lake Lugo, thus gillnet being used at the Lake may not remove the juveniles before replacing the next generation to sustain the yield. Capture size of the stock should be determined taking into account the L_{50} of females, which may otherwise remove the spawning fish during their peak breeding season. Lack of enforcement actions on fisheries resource legislation had severe negative impact on the stocks of the shoreline spawning *C. gariepinus* and *C. carpio* species aggregations during summer spawning seasons. Therefore, there is an urgent need for an action towards the sustainable utilization of the lake resources by applying fishery management tools.

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