Abyss. J. Sci. Technol. Vol. 3, No. 1, 2018, 13-19
ISSN 2616 – 4728 (Online); 2616 – 471X (Print)

Abyssinia Journal of Science and Technology

Length-weight Relationships, Sex ratios and Size at First Maturity of Fishes of Lake Ardibo, South Wollo, Ethiopia

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ABSTRACT

This study was to investigate some biological aspects of commercially important fishes of Lake Ardibo which was conducted on monthly basis from October 2013 to September 2017 to know Length-weight relationships, sex ratios and size at first maturity of *Oreochromis niloticus* and *Cyprinus carpio*. Gillnets of different mesh sizes (6, 8, 10 and 12 stretched mesh size) were used to sample the fishes. Total length (TL) and total body weight (TW) of all species were measured to the nearest 0.1 cm and 1 g, respectively. The results of the study showed that the length-weight relationships for *O. niloticus* ($TW = 0.020TL^{2.934}$; $n = 243$; $r^2 = 0.936$) and for *C. carpio* ($TW = 0.019TL^{2.845}$; $n = 1436$; $r^2 = 0.927$) and showed a curvilinear relationship, signifying the fishes growth were negative allometric growth, *O. niloticus* have significant difference between sexes (χ^2, $P<0.05$), However C. *carpio* was insignificant at (χ^2, $P > 0.05$) and the size at first sexual maturity (L_{50}) for *O. niloticus* of females 16.5 cm and 15.4 cm for males and for *C. carpio* of females 19.23 cm and 19.24 cm for males, respectively. By using the fish growth parameters the Study Lake Fishes were found in poor condition with compared to the fishes that exist in other water bodies in Ethiopia. During our exploratory survey the unregulated open access resource use and uncoordinated water resources development activities were performed which cause degradation of other natural resources in general and fish resources in particular.

Keywords: Fish, Lake Ardibo, Length-weight relationship, Sex ratio, Size at first Maturity.

INTRODUCTION

Ethiopia is a land locked country that depends on the inland waters for the supply of fish as a cheap source of animal protein. It has a number of lakes and rivers with substantial quantity of fish stocks (Tesfaye, 1998). The inland water body of Ethiopia is estimated at about 7400 km^2 of lake area and about 7000 km total lengths of rivers (Wood & Talling, 1998). Fishes provides about 20 percent of animal protein intake in developing countries this can reach 90 percent in small island developing states or coastal areas and also contribute indirectly to food security by providing revenue for food-deficient countries to purchase food. Fish exports from low-income, food deficient countries are equivalent to 50 percent of the cost of their food imports (Breuil, 1995). These water bodies support a diverse aquatic life including more than 183 fish species that represent 12 orders, 29 families, and 70 genera (Golubtsov & Mina, 2003). In Ethiopia, Per-capita production from the capture fishery is less than 240 g/person/year which is very small in Sub-Saharan Africa (FAO, 2012).

Length–weight relationships (LWRs) of freshwater fishes are useful in determining weight and biomass when only length measurements are available and are required in fishery management and conservation (Froese, 1998; Oscoz et al., 2005). These relationships also enable the computation of condition indices and allow for comparisons of species growth trajectories between sexes, different seasons, and regions (Froese, 2006). The relationship between total length (TL) and total weight (TW) typically takes the allometric form: $TW= aTLb$, or in the linear form: $LogTW = Loga + bLogTL$, where 'a' and 'b' are constants estimated by regression analysis. If fish retains the same shape, it grows isometrically and the length exponent "b" has the value $b = 3.0$. The b values above 3 indicates positive allometric growth where fish becomes heavier for its length while b values below 3 means that the fish becomes lighter for its length therefore negative

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allometric growth (Ratnakala et al., 2013). The slope 'b' is affected by stage of sexual maturity, nutritional adequacy of the diet, and toxicology of the environment (Begenal and Tesch, 1978). Tilapia is the leading species caught and consumed in Ethiopia, although this does not seize for all groups and for all areas. Nile tilapia (*Oreochromis niloticus*) is the dominant fish species of the landings (Gebremariam et al., 1989). At present, *C. carpio* is one of the most commercially important fish species that often forms the basis of commercial fisheries and the most desired fish species by the local community among the commercially exploited fish species in Lake Ziway (Lemma et al., 2015). However, Mathewos (2013) suggest that the ecological impact of such an introduction could be undesirable because the species is known to be a potential pest in many countries for which data are available.

Studies on length-weight relationships, sex ratio and size at first maturity of threatened fishes are the most important biological parameters to provide information on the growth and condition of fish species and the entire fish communities are highly significant for management and conservation of populations in natural water bodies (Sarkar et al., 2009; Hossian et al., 2012). Proper estimation of size at first maturity (L_{50} - length at which 50% of the fish are mature) is very useful for fish stock management. This information is crucial in formulation of management options especially in the choice of gear to be used in capture fisheries. It can guide the managers in setting mesh sizes that will target mature fish which have contributed to the next generation giving juvenile fish time to grow and mature (Karna et al., 2012). The recognition of maturity status of fish is based on visual and subjective descriptions of ovaries and testes at different maturation stages. The biology of fishes from different water bodies in Ethiopia have been studied by various scholars. In Amhara region, Lake Ardibo is one of the major lakes that has high fish productions potential and this has been currently used for irrigation, cloth washing, swimming, local fishing activity and watering of animals. Nile tilapia and common carp are the most desired fish species by the local community and commercially exploited fish species in Lake Ardibo. Therefore, the present study is designed to generate crucial information on length-weight relationships, sex ratios and size at first maturity of fishes in Lake Ardibo. The information will contribute for sustainable utilization, management and conservation of the fish species.

MATERIALS AND METHODS

Description of the study area:

Lake Ardibo is found in northern Ethiopia, South Wollo administrative zone Tehuledre Woreda (Fig. 1). It is located at $11^0$10'26.9" N, $39^0$45'19.2" E at an altitude of 2000 m asl. The climate is sub humid with regular yearly temperature and precipitation of 18°C and 1158 mm, respectively. Lake Ardibo

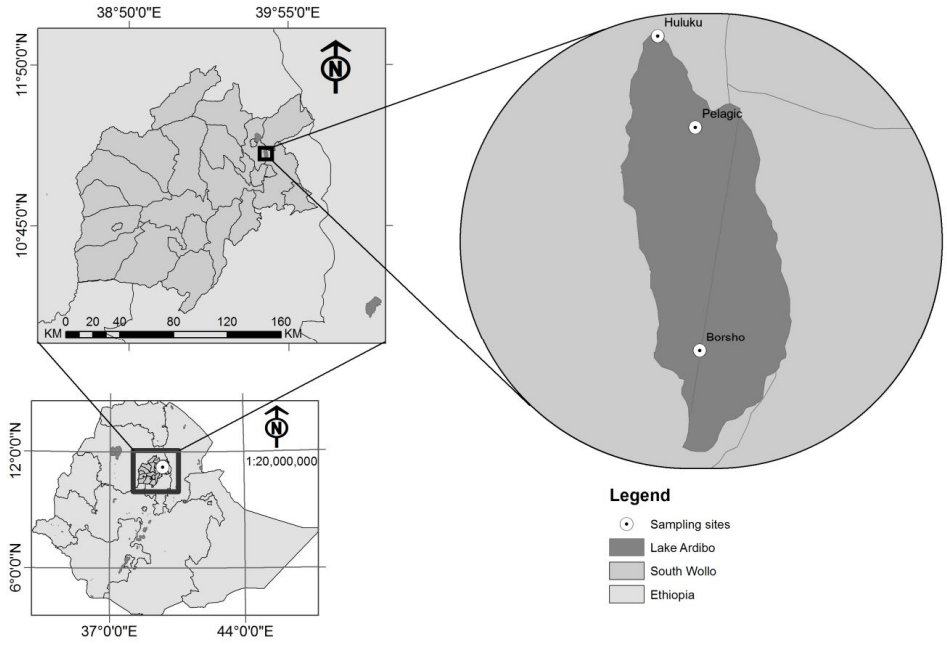

Fig. 1: Map of the Lake Ardibo with sampling sites.

has utmost depth of 65 m (Wubshet et al., 2018). Lake Ardibo and the surrounding area have high elevation/altitude described by spread trees and bushes as well as natural-grazing field. In Lake Ardibo, fishing activities carried out using narrow sized gillnet (< 8cm, below the standard) which might be responsible for under sized fishes in the lake

Sampling site and data collection:

Three sample sites, Hulluko, Borsho and pelagic were selected purposively based on vegetation cover, human and animal interference intensity. In each sampling site, fish specimens were taken every month from October 2013 to September 2017. Gillnet of various stretched mesh sizes 6, 8, 10 and 12 cm were used to catch fish specimens. The nets were set 5:00 pm late afternoon and retrieve 7:00 am in early morning. Immediately after capture from all specimens, the total length (TL) of each fish was taken from tip of snout (mouth closed) to the extended tip of the caudal fin. For each individual, the TL was measured in centimeter using measuring board and the total body weight (TW) was measured in grams to the nearest 0.1 gram using electronic weighing balance. The degree of sexual maturity and sex of each specimen were determined by inspection of the gonads in fresh individuals using maturity scale (Holden & Raitt, 1974)

Length-weight relationship was determined using power function (Bagenel & Tesch, 1978) $TW= aTL^b$, Where TW = Total weight (gm), 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 (coefficient of determination) was estimated by regression analysis. The statistical significance level of r^2 was estimated, and 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' fish species. Chi-square test was employed to test if sex ratio varied from 1:1 in monthly samples, in various size classes and in the total sample.

Length at first maturity (L_{50}):

The L_{50} was estimated by: TL = a/-b (Sparre and Venema, 1998): a = intercept, b = slope of regression

Data analysis:

The collected data were analyzed using descriptive and inferential statistics (Regression, ANOVA and Chi-square test) through application of Excel window 10 and SPSS statistical soft version 22. All the statistical analyses were considered at significance level of 5% ($p < 0.05$)

RESULTS

Length-weight relationship:

A total of 1679 individuals were collected during this study period, from these 1436 were *C. carpio* and 243 were *O. niloticus*.These sampled specimens were small since the lake fisheries were highly exploited by the fishermen. The range and mean length and weight of *C.carpio were* 10 - 46.2 cm, 21.4±5.8cm and 24-1161g, 144.7±115.4 g respectively. The range and mean length and weight of *O.niloticus* were 15-35 cm, 18.2±3.88 cm and 31-460g, 113±95.3 g. respectively. The relationships between total length and total weight for *C. carpio* and *O. niloticus* were curvilinear and statistically significant ($P < 0.05$) (Fig. 2). Therefore, *C. carpio* and *O. niloticus* in Lake Ardibo exhibits negative allometric growth as the value of "b" was less than 3 (Fig. 2).

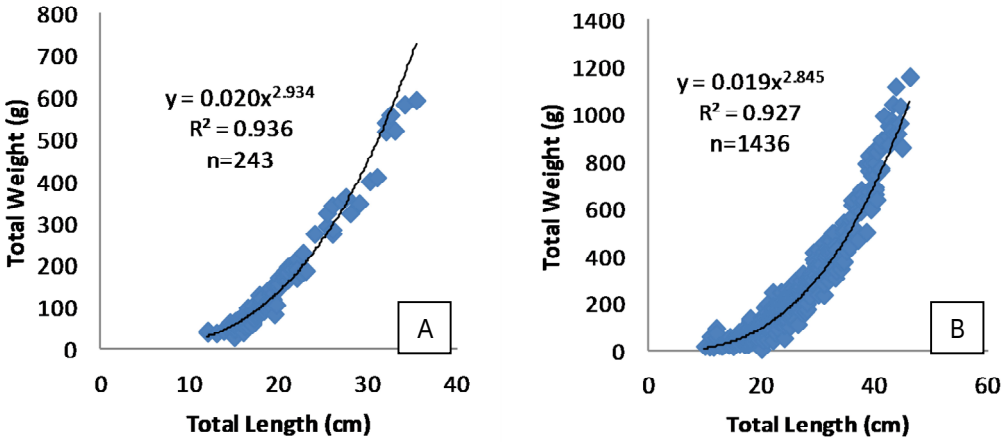

Fig. 2: Length-weight relationship of (A = *Oreochromis niloticus, B= Cyprinus carpio)* in Lake Ardibo

Sex ratio:

The sex ratio for *O. niloticus* had significant difference ($\chi 2$, $p < 0.05$). On contrary it was insignificant for *C. carpio* ($\chi 2$, $p > 0.05$) that shows female to male sex ratio deviation from 1:1 in *O.niloticus* unlike *C.carpio* in Lake Ardibo (Table1).

Table 1: Sex ratio of *C. carpio* and *O. niloticus* in Lake Ardibo.

Fish species	Females	Males	F: M	χ^2
C. carpio	690	746	0.92:1	2.2^{ns}
O. niloticus	171	72	2.38:1	40.3*

ns=insignificance, *= Significance, F: M = Female to Male sex ratio

Size at first maturity:

The total length at which L_{50} reached maturity of the *O. niloticus* and *C. carpio* in Lake Ardibo were calculated using $L_{50} = a/-b$ (Sparre and Venema, 1998) and shown below in Table 2. The L_{50} of males and females *O.niloticus* and *C.carpio* were 15.4 cm, 16.5cm and 19.24cm and 19.23cm respectively (Table 2). Based on the current study, the male *O.niloticus* reached sexual maturity at smaller size than females. However, the males and females of *C.carpio* attained first sexual maturity at almost the same sizes.

DISCUSSION

Length-weight relationship:

The values obtained for the length-weight relationship showed that *C. carpio* (b = 2.845) and *O. niloticus* (b = 2.934) had negative allometric in their growth. Several authors have reported both isometric and allometric growth for *C. carpio* and *O. niloticus* from various water bodies. The value of "b'' for combined sexes data in this study is comparable to the value of b calculated for the same species (*O. niloticus)* in Lake Ardibo; b=3.2505 (Wubshet, 2010), in Lake Awassa; b = 2.91 (Demeke, 1990), in Lake Tana Zenebe (1997) & Dereje (2014) reported; b = 2.74, b = 3.12, respectively. *Cyprinus carpio* in Lake Ardibo; b= 2.8261(Wubshet, 2010), in Amerti reservoir showed b = 2.923 (Mathewos, 2013) and b = 2.93 in Lake Ziway (Lemma et al., 2015). The parameters of the length-weight relationships (LWRs) might be affected by various factors including season, sex, differences in the length range of the caught specimens, population density, sexual maturity, age, habitat, stomach fullness, food quality or quantity, preservation techniques, fish health or environmental conditions (Cox & Hinch, 1997). The variations 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, sex and stage of maturity), habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions (Abowei et al., 2009; Bagenal & Tesch, 1978; Froese, 2006; Pauly,1984; Sarkar et al., 2013; Sparre & Venema, 1992; Wootton, 1998). The coefficient of determination (r^2) for length-weight relationships was high for both fish species which indicated that the length increased with increase in weight of the fish (Tah et al., 2012; Koffi et al., 2014). This was in agreement with previous studies on different fish species from various water bodies.

Sex ratio:

The sex-ratio (F: M) for *O. niloticus* and *C. carpio* in Lake Ardibo were 2.38:1, 0.92:1, respectively. For *O. niloticus* statistically which is deviated from the expected 1:1 in favor of females. Contrary this was did not deviate from unity in Lake Ardibo (Wubshet, 2010), However, This agrees with the results obtained for the same species for *O. niloticus* in Lake Awassa (Demeke, 1994), in Lake Hayq (Workiye, 2014), in Lake Tana (Dereje, 2014), in Lake Naivasha (Njiru et al., 2014). On the contrary, sex ratios of the same species where male population dominate over females were reported in Lake Tana (Zenebe, 1997) and in Lake Victoria (Njiru et al., 2006). The sex ratio of *C. carpio* was significant different from 1:1 in Lake Ardibo (Wubshet, 2010), the sex ratio of *C. carpio* was not differ significantly from 1:1 ($\chi 2 = 2.33$; $P = 0.126$) in Amerti reservoir (Mathewos, 2013). Although concrete evidence couldn't be drawn for

Table 2: Length at first sexual maturity (L_{50}) of fish species determined by different authors at different years.

Fish Species	Present study Lake Ardibo		Demeke, 1994 Awassa		Dereje, 2014 Tana		Fasile, et al., 2012 Fincha	
	F	M	F	M	F	M	F	M
O. niloticus	16.5	15.4	18.8	19.8	21.2	23.4	21.8	24.5
C. carpio	19.23	19.24	-	-	-	-	37.50	24.50

F = Females, M = Males

biased sex ratio for the present study, it may be caused by sexual segregation during spawning, behavioral differences between the sexes, gear type and fishing site (Demeke, 1994). This could be because of the difference in growth rate of both sexes. Other biological mechanisms such as differential mortality rates or differential migratory patterns between the male and female sexes may also cause unequal sex ratios.

Size at first sexual maturity:

The size at 50% maturity of the *O. niloticus* and *C. carpio* for females were much smaller than those reported by other authors. According to Wubshet (2010) the size at first sexual maturity of males and females ware 16cm and 18cm and 17cm and 19cm for *O. niloticus* and *C. carpio* respectively. For the same species (*O.niloticus*) length at maturity was 42 cm for both sexes in Lake Chamo (Yirgaw et al., 2001), 17cm for box sexes in Lake Naivasha (Njiru et al., 2014). Thus, the lengths at first maturity of *O. niloticus* both sexes in Lake Ardibo were smaller than those in Lakes Awassa, Tana and Chamo similarly the length at first maturity of *C.carpio* was smaller than Fencha Reservoir. Length at first maturity in many fish species relies on demographic conditions and is determined by genes and environment, change in Lake water level and associated factors, poor condition or overfishing and these lead to a dramatic decrease in size at 50% sexual maturity fish. In poor condition, fishes mature at small size than those in good condition (Lowe- McConnell, 1958; Cowx, 1990), the abundance and seasonal availability of food, temperature, photoperiod, dissolved oxygen (Babiker & Ibrahim, 1979; Bwanika et al., 2004), predation and competition may be responsible for the small size at first maturity (Bwanika et al., 2004). Therefore, the smaller size at maturity of *O. niloticus* in Lake Ardibo could be attributed to the increases in fishing mortality as a result of the excessive fishing effort, they reached maturity at lower size in order to perpetuate their own offsprings losses due to illegal fishing practices.

In conclusion, *O. niloticus* and *C. carpio* showed negative allometric growth in Lake Ardibo. The length-weight relationship of both fish species was statistically significant and the line fitted with curvilinear relationship between length and weight. In Lake Ardibo, male *O. niloticus* matured at smaller size than females whilst female *C. carpio* matured at smaller size than males. Therefore, 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. We conclude that male and female *O. niloticus* in Lake Ardibo during the study period were not equally distributed. But the sex ratio of *C. carpio* was not significantly different ($p < 0.05$) from a hypothetical 1:1 ratio; Therefore *C. carpio* in Lake Ardibo during the study period were equally distributed. Generally, the fish population of both species attained the size at first maturity at smaller size due to overfishing, over exploitation. Therefore, we recommend that the fishermen and the community should use gillnet of stretched mesh size >8cm (recommended size) and limit the number of fishing efforts (the number of gill net, and non-motorized boat) for sustainable utilization of the fisheries of the lake.

ACKNOWLEDGEMENTS

We are greatly obliged to thank Amhara Agricultural Research Institute for financial support and Hayq Agricultural Research Sub-Center, Sirinka Agricultural Research Center for warm hospitality and support in all aspects of our inquiry for this project. We would also to extend our gratitude to Assefa Biru and Wubu Kassaw who are boat and car drivers respectively.

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