

Differences in Phenotypic Characters of Nile Tilapia (*Oreochromis niloticus* L) in Three Ethiopian Rift Valley lakes; Screening Strains for Aquaculture

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ABSTRACT

Nile tilapia (*Oreochromis niloticus* L.) is indigenous species to Ethiopia and constitutes major proportion in the country's fish production. In an attempt to select better performing strains for aquaculture development, tilapia populations from different Ethiopian rift valley lakes showed different growth performances in pond culture. Investigation of desired culture characteristics of target tilapia populations is required to improve their productivity in aquaculture system. The current study was made to investigate phenotypic characters of the tilapia populations in three geographically isolated Ethiopian rift valley lakes (Chamo, Koka and Ziway). A total of 450 adult tilapias of commercial catches were sampled from the three lakes and their phenotypic characters were analyzed during May 2018 to March 2019. Twenty six morphometric character indices, eight meristic counts, total length, standard length, total weight, length-weight relationship and Fulton's condition factor were considered in the analysis. The results revealed significant differences ($p \leq 0.05$) in most of the morphometric character indices, meristic counts, mean length and weight and Fulton's condition factor among the three tilapia populations. Chamo tilapia population were found to have highest mean values of total weight, total length and standard length while Koka population have highest mean value of Fulton's condition factor and positive allometric growth as characters desired in aquaculture. Further research is required to investigate whether the fish populations could maintain those characters in pond cultures.

Keywords: Aquaculture; Geographically isolated; Meristic; Morphometric

INTRODUCTION

Nile tilapia (*Oreochromis niloticus* L.) is cultured worldwide and currently ranked second only to carps in global farmed food fish. The fish is indigenous species to Ethiopia and constitutes major proportion (65%) in the country's fish production [1]. In the aquaculture development efforts of Ethiopia, wild *O. niloticus* were collected from natural environments, especially from the Ethiopian rift valley lakes and stocked into ponds. In an attempt to select better performing strains for aquaculture, tilapia populations from different Ethiopian rift valley lakes showed different growth performances in pond culture. Growth performances of four *O. niloticus* populations of Ethiopian rift valley lakes (Hawassa, Chamo, Koka and Ziway) were evaluated in pond culture at Batu Fishery and other Aquatic Life Research Center [2] where the Chamo population was found to grow significantly faster than others. Similar studies were conducted to evaluate the growth performances of the tilapia populations

of Ethiopian rift valley lakes in pond culture at different times for different experimental periods and found variation in growth performances [3,4] whereby the Koka and Ziway tilapia populations were mentioned as promising candidate populations for aquaculture development in Ethiopia compared to tilapia populations of Hora, Hawasa and Metehara lakes in Figure 1-3.

The three lakes, Chamo, Koka and Ziway are geographically isolated situated in different sub-drainage basins: Abaya-Chamo, Ziway-Shala and Awash basins, respectively, all within the Ethiopian Rift Valley [5]. Chamo has more diversified ichthyofauna than other lakes in Ethiopia except Lake Abaya. There are six important fish species for fishery in Chamo. These, according to LFDP [6] are Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*), labeo (*Labeo horie*), African catfish (*Clarias gariepinus*), Bagrus (*Bagrus docmak*) and Barbus (*Labeobarbus intermedius*). The *O. niloticus*, *L. niloticus* and *C. gariepinus* were numerically the three dominant species in the fish landings [7]. Koka harbors three

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commercially important fish species: Nile tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*) and African catfish (*Clarias gariepinus*) where *O. niloticus* were found in healthy state, *C. gariepinus* have shown signs of growth overfishing and *C. carpio* have shown under exploitation [8]. Indigenous fish species such as Nile tilapia (*Oreochromis niloticus*), Barbus (*Labeobarbus intermedius*), straightfin barb (*Barbus paludinosus*) and Garra (*Garra dembecha*), and introduced fish species such as African Catfish (*Clarias gariepinus*), Crucian carp (*Carassius carassius*), Common carp (*Cyprinus carpio*) and Tilapia zillii (*Coptodon zillii*) are found in Lake Ziway [9]. Among these species, Nile tilapia, African catfish, Crucian carp and Common carp are commercially important ones. Studies indicated [9] that the current annual fish production from Lake Ziway is declining, particularly the population of the Nile tilapia declined tremendously.

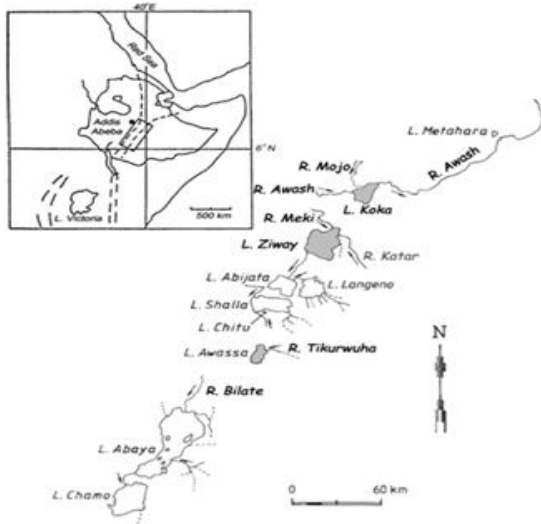


Figure 1: Location of the Ethiopian rift valley lakes.

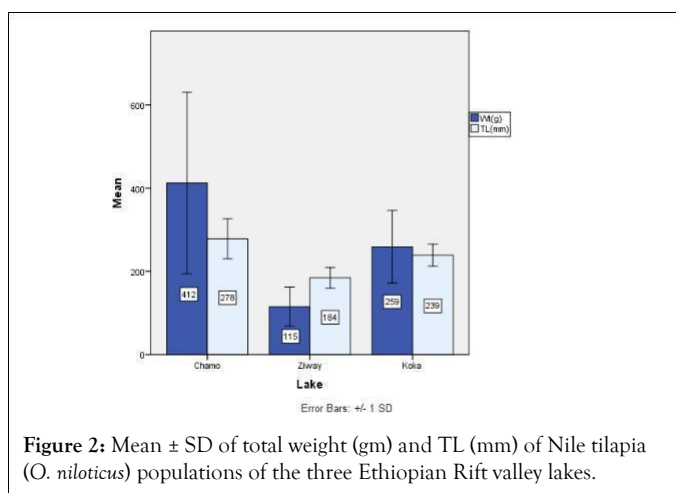


Figure 2: Mean \pm SD of total weight (gm) and TL (mm) of Nile tilapia (*O. niloticus*) populations of the three Ethiopian Rift valley lakes.



Figure 3: *O. niloticus* samples of lakes Chamo (left), Koka (middle) and Ziway (right).

Aquatic environment of the three lakes in terms of their basic morphometric features, altitude, water quality parameters and fish species diversity are different [10]. Under these different environmental conditions of the three lakes, tilapias are expected to develop different phenotypic and genetic characters. Phenotypic variation is wide in organisms spread in different geographical locations, and often involves ecologically relevant behavioral, physiological, morphological and life historical traits. Phenotypic plasticity can be inclusively defined as the production of multiple phenotypes from a single genotype, depending on environmental conditions [11].

Characterization of the tilapia population helps in utilization of the resource in aquaculture, and further contributes to protect the population in their natural environment. Hence, the objective of the present study was to investigate desired culture characteristics of *O. niloticus* of rift valley lakes in order to improve their productivity in aquaculture system with specific objective of characterizing the *O. niloticus* populations of Chamo, Koka and Ziway Lakes based on their phenotypic characters.

MATERIALS AND METHODS

Description of the study areas

The fish were sampled from three Ethiopian rift valley lakes: Chamo, Koka and Ziway lakes from May, 2018 to March 2019. These water bodies were selected for their targeted Nile tilapia (*O. niloticus*) populations to be used in the development of aquaculture in Ethiopia. Lake Chamo is situated in South most part of the Ethiopian rift valley lakes. The lake has surface area of about 297 km² [12] and recharged mainly by a feeder river called Kulfo. Lake Koka is a manmade reservoir located at about 90 km Southeast of Addis Ababa between 8° 18' 57" to 8° 28' 21" N and 39° 0' 0" E to 39° 9' 18" E at an altitude of 1,590 m.a.s.l. It was constructed on Awash River in 1960 for the purpose of hydro-electric power generation.

The reservoir has a surface area of about 255 km² with a maximum and mean depth of 14 m and 9 m, respectively [6]. Lake Ziway, spelled also as Zeway, Zway or Zwai (locally called as Lake Danbal) is located in the Ethiopian rift valley between 7° 52' to 8° 8' N and 38° 40' to 38° 56' E at an altitude of 1636 m a.s.l. with maximum length of 32 km and maximum width of 20 km [6]. The lake is the second largest lake in Ethiopian rift

valley after Abaya Lake, having an area of 434 km² and shore line length of 137 km. The Lake is, however, the shallowest of the rift valley lakes with maximum and mean depth of 8.95 m and 2.5 m, respectively [6]. The lake has two feeder rivers, Meki River from Northwest and Katar River from East side, and has one outlet river in its Southern part, the Bulbula River, which seasonally flows into Abijata Lake.

Phenotypic characterization of the *Oreochromis niloticus*

Morphometric characters and meristic counts following described methods [11] were recorded from at least 150 fish samples of each of the tilapia populations of the three study lakes in Table 1.

Table 1: Morphometric and meristic characters of *O. niloticus* populations of the three lakes.

A. Morphometric analysis			
Characters	Acronyms	Characters	Acronyms
Total length	TL	Caudal peduncle length	CPL
Standard length	SL	Caudal peduncle width	CPW
Head length	HL	Caudal peduncle depth	CPD
Body depth	BD	Pectoral fin length	Pec FL
Body width	BW	Dorsal fin base length	DFBL
Head width	HW	Pelvic fin base length	Pel FBL
Abdomen length	AL	Length of longest dorsal fin spine	LLoDFS
Orbit diameter	OD	Length of last dorsal fin spine	LLaDFS
Pre-orbital length	Pr-OL	Length of longest dorsal fin ray	LLoDFR
Post-orbital length	Po-OL	Length of last dorsal fin ray	LLaDFR
Trunk length	TrL	Length of longest anal fin spine	LLoAFS
Pelvic fin length	Pel FL	Length of first anal fin spine	LFiAFS
Anal fin base length	AFBL	Length of longest anal fin ray	LLoAFR
Caudal fin length	CFL	Length of last anal fin ray	LLaAFR
B. Meristic analysis			
Characters	Acronyms	Characters	Acronyms
Dorsal fin spines count	DFSC	Pectoral fin rays count	Pec FRC
Dorsal fin rays count	DFRC	Anal fin spines count	AFSC
Pelvic fin spines count	Pel FSC	Anal fin rays count	AFRC
Pelvic fin rays count	Pel FRC	Caudal fin rays count	CFRC

Along with the morphometric measurements, weight (TW) of each specimen was measured to the nearest 0.1 g. At least 150 fishes per lake were assessed. Condition factor of each fish was measured using the following equation:

$$K=100 (TW/TL^3)$$

Where, k=Fulton's condition factor

TW=total weight in grams

TL=total length in centimeter

The fish were characterized based on the morphometric and meristic parameters. Values for the quantitative traits of the populations were expressed as mean and standard deviation as mean \pm SD. Differences in mean values of the traits between the populations were analyzed in one-way analysis of variance (ANOVA) at significance level of $p \leq 0.05$ using Tukey's mean separation method [13,14].

RESULTS AND DISCUSSION

In this phenotypic characterization, parameters including morphometric character indices, meristic counts, total weight total length, standard length and fish condition factor were analyzed from a total of 450 samples: 150 fish samples for each of the populations in Table 2.

Table 2: Means and standard deviations of quantitative phenotypic traits based on morphometric character indices and meristic counts.

Characters	Population		Pel FRC	
	Chamo	Koka	Ziway	
Morphometric indices				
HL/SL	0.324 \pm 0.02	0.312 \pm 0.01	0.324 \pm 0.02	
BD/SL	0.392 \pm 0.02	0.360 \pm 0.02	0.370 \pm 0.02	
BW/SL	0.158 \pm 0.01	0.170 \pm 0.01	0.167 \pm 0.02	
HW/HL	0.550 \pm 0.03	0.559 \pm 0.03	0.553 \pm 0.10	
AL/SL	0.302 \pm 0.02	0.314 \pm 0.03	0.304 \pm 0.02	
OD/HL	0.209 \pm 0.03	0.220 \pm 0.03	0.249 \pm 0.09	
Pr-OL/HL	0.320 \pm 0.03	0.287 \pm 0.03	0.312 \pm 0.24	
Po-OL/HL	0.497 \pm 0.03	0.493 \pm 0.03	0.484 \pm 0.09	
TrL/SL	0.681 \pm 0.03	0.710 \pm 0.02	0.690 \pm 0.06	
PelFL/SL	0.257 \pm 0.02	0.273 \pm 0.05	0.263 \pm 0.02	
AFBL/SL	0.194 \pm 0.01	0.195 \pm 0.01	0.182 \pm 0.01	
CFL/TL	0.200 \pm 0.01	0.201 \pm 0.01	0.203 \pm 0.11	
CPL/TL	0.119 \pm 0.01	0.113 \pm 0.01	0.120 \pm 0.01	
CPW/TL	0.040 \pm 0.00	0.044 \pm 0.01	0.040 \pm 0.01	
CPD/TL	0.105 \pm 0.01	0.098 \pm 0.01	0.096 \pm 0.01	
PecFL/SL	0.365 \pm 0.02	0.342 \pm 0.04	0.359 \pm 0.02	
DFBL/SL	0.598 \pm 0.03	0.622 \pm 0.06	0.601 \pm 0.03	
PelFBL/SL	0.056 \pm 0.01	0.052 \pm 0.01	0.055 \pm 0.01	
LLoDFS/SL	0.156 \pm 0.01	0.141 \pm 0.02	0.149 \pm 0.01	
LLaDFS/SL	0.156 \pm 0.01	0.141 \pm 0.02	0.149 \pm 0.01	
LLoDFR/SL	0.250 \pm 0.03	0.224 \pm 0.03	0.217 \pm 0.02	
LLaDFR/SL	0.077 \pm 0.01	0.082 \pm 0.01	0.080 \pm 0.01	
LLoAFS/SL	0.151 \pm 0.01	0.138 \pm 0.02	0.149 \pm 0.02	
LFiAFS/SL	0.064 \pm 0.01	0.050 \pm 0.01	0.056 \pm 0.01	
LLoAFR/SL	0.226 \pm 0.02	0.221 \pm 0.03	0.215 \pm 0.01	
LLaAFR/SL	0.075 \pm 0.01	0.081 \pm 0.01	0.076 \pm 0.01	

Meristic counts			
DFSC	16.59 ± 0.49	16.82 ± 0.39	16.85 ± 0.37
DFRC	12.29 ± 0.49	12.21 ± 0.41	12.09 ± 0.46
Pel FSC	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00
Pel FRC	5.00 ± 0.00	5.00 ± 0.00	5.00 ± 0.00
Pec FRC	13.06 ± 0.35	12.63 ± 0.51	12.42 ± 0.56
AFSC	3.00 ± 0.00	3.00 ± 0.00	3.00 ± 0.00
AFRC	9.29 ± 0.47	9.53 ± 0.54	9.48 ± 0.51
CFRC	17.46 ± 0.88	17.23 ± 0.98	17.93 ± 0.61
TW(g)	412.24 ± 218.21	259.17 ± 87.65	115.13 ± 47.14
TL(mm)	278.15 ± 47.89	239.00 ± 26.35	184.43 ± 24.61
SL(mm)	225.63 ± 41.73	191.74 ± 22.26	149.44 ± 20.59
Condition factor (K)	1.78 ± 0.16	1.83 ± 0.22	1.75 ± 0.14

Nile tilapia population of Lake Chamo were characterized by highest mean weight (412.24 ± 218.21 g), total length (278.15 ± 47.89 cm) and standard length (225.63 ± 41.73 cm), which differed significantly ($p \leq 0.05$) from similar parameters of populations of lakes Koka and Ziway. The current mean total length of tilapia population of Lake Chamo is within the range of 19-43 cm length reported [7]. The Chamo population have also scored highest morphometric character indices of BD/SL, CPD/TL, Po-OL/HL, PelFBL/SL, LLoDFS/SL, LLaDFS/SL, LLaDFR/SL, FiAFS/SL, LLoAFR/SL and highest record of meristic character in PecFRC in which all the characters differed significantly ($p \leq 0.05$) from the mean values measured from the populations of lakes Koka and Ziway. However, the population in Lake Chamo scored significantly ($p \leq 0.05$) lowest mean values of BW/SL, TL/SL and LLaDFR/SL from morphometric indices, and DFSC and AFRC from meristic characters. Generally, *O. niloticus* population from Lake Chamo were found to be larger in total length and weight, shorter at trunk region with respect to their standard length, dorso-ventrally deep, laterally compressed in body form as compared to other populations. They also had longest pre-orbital region, dorsal and anal fins as indicated in their morphometric indices.

Nile tilapia populations of Lake Koka scored mean weight of 259.17 ± 87.65 g, mean total length of 239.00 ± 26.35 cm and standard length of 191.74 ± 22.26 cm; values which were significantly ($p \leq 0.05$) lower than that of Chamo population but higher than that of Ziway population. A mean total length that a fish of a given stock would reach if they were to grow indefinitely (L_{∞}) was estimated to reach 44.5 cm for the *O. niloticus* population of Koka [8] and 28.1 cm for the *O. niloticus* population of Ziway [15]. The size differences between the population means in the current result agrees with the above reports. Highest mean score of Fulton's condition factor (K) was obtained in population of Lake Koka (1.83) and the value differed significantly ($p \leq 0.05$) from that of the populations of lakes Chamo (1.78) and Ziway (1.75). The average K-values of *O. niloticus* were reported to vary over time; 1.87 for Koka population [16] and 1.89 [17] and 1.81 [15] for Ziway and 2.35 for Chamo [18]. The population of Lake Koka scored highest morphometric character indices of AL/SL, TL/SL, DFBL/SL, CPW/TL, PelFL/SL and LLaAFR/SL but lowest

mean values of HL/SL, BD/SL, CPL/TL, PecFL/SL, PelFBL/SL, LLoDFS/SL, LLaDFS/SL, LLoAFS/SL, and LFiAFS/SL which were significantly different ($p \leq 0.05$) from that of lakes Chamo and Ziway populations. As compared to populations of lakes Chamo and Ziway, the Koka *O. niloticus* population were generally found to have longer trunk region, laterally wide (fat), not dorso-ventrally deep, with shorter head and fin spines.

The tilapia population of Ziway were significantly ($p \leq 0.05$) lower in their mean total weight (115.13 ± 47.14 g), mean total length (184.43 ± 24.61 cm) and standard length (149.44 ± 20.59 cm) than the lakes Chamo and Koka populations. The population had also lowest morphometric character indices of LLoDFR/SL, AFBL/SL, LLoAFR/SL and the lowest meristic counts of dorsal and pectoral fin rays which were significantly ($p \leq 0.05$) different from mean values observed in that of Lakes Chamo and Koka populations. However, the population scored the highest mean value of OD/HL morphometric character index and the highest mean caudal fin ray count and differed significantly from that of lakes Chamo and Koka. Generally, *O. niloticus* population of Lake Ziway was relatively smaller in size, have shorter dorsal fin rays and wider orbit diameter with respect to their head length.

Morphometric characters in fish have been demonstrated to be influenced by environmental factors [19]. Chamo and Ziway are natural lakes while Koka is an artificial lake constructed for hydro-electric power generation. Aquatic environment of the three lakes in terms of their basic morphometric features, altitude, water quality parameters and fish species diversity are different [10]. The *O. niloticus* populations of the three lakes are accordingly isolated for centuries and developed different morphometric characters to adapt to their corresponding environmental conditions.

Fulton's condition factor (K), which indicates the nutritional level and status of the fish over time, might be greatly influenced by environmental factors. The higher Fulton's condition factor (K), observed in *O. niloticus* population of Lake Koka in the current study could be resulted as a function of better feed availability in artificial reservoirs than in natural lakes. Though the degree vary from lake to lake, anthropogenic impacts such as pollution due to silt and nutrient load from watershed areas, municipal waste, industries (tannery, flower culture), water level fluctuation and fishing pressures have directly or indirectly affected the fish community in the lakes [20]. Floodplains associated with the reservoirs are generally known to be most productive aquatic ecosystems. The K value of *O. niloticus* population of lakes Chamo, Koka and Ziway varied over time based on environmental changes [16-18].

Phenotypic adaptations of fish to their environment do not necessarily cause a change in genetic constitutions of the population [21] and hence phenotypic differences among populations cannot usually be taken as evidence of genetic differentiation. However, the *O. niloticus* populations of the three lakes are isolated for geological time that development of genetic differences among the populations is most likely. In genetic analysis using total mtDNA digestions, Seyoum

and Kornfield [22] grouped *O. niloticus* of Ethiopia into different subspecies: *O. n. cancellatus* (Awash basin), *O. n. filowa* (Sodore hot springs), *O. n. taita* (Tana population).

[23] using allozyme, clustered natural populations of *O. niloticus* in the Ethiopian Rift valley (Lakes Ziway, Hawasa, Koka and Sodore hot springs) in one group and populations of Tana, Nile, Kenya in other group. The authors [20] considered the subspecies classification made by the former study [22] was premature. According to the species clustering of the later authors [23], the *O. niloticus* of Lake Chamo can be related to the Kenyan and Nile group since the Abaya-Chamo basin connects down to the Chew Bahir and Turkana Lake in northern Kenya.

In a study of phylogenetic differentiation of wild and cultured Nile tilapia populations based on phenotype and genotype analysis [11], it was reported that phenotype analysis based on a large number of morphometric character indices and meristic counts can be used to discriminate fish populations up to the intraspecific level with the same results as the genotype analysis based on random amplified polymorphic DNA (RAPD) fingerprinting. Hence, the differences observed in phenotypic characters of the three *O. niloticus* populations in the present study based on the analysis made using 26 morphometric character indices, 8 meristic counts and four other morphometric characters indicates that the differences have also potential genetic bases.

CONCLUSION

Based on the parameters considered for characterization, Nile tilapia (*O. niloticus*) populations of lakes Chamo, Koka and Ziway differed in many phenotypic characters in their natural environments. As desired characters in aquaculture production, tilapia population of Lake Chamo had higher mean weight and length than population of Lake Koka followed by population of Lake Ziway.

The phenotypic characters are governed by genetic and/or environmental factors. Thus, it is important to confirm whether the populations could maintain these characters when grown under controlled environments.

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REFERENCES

1. Abegaz H. Fish production from the perspective of Development Goals of Ethiopia. In EFASA 2015, Proceedings of the VIIth Annual Conference and Workshop of EFASA, Arba Minch, Ethiopia. 2015; pp: 5-16.
2. Tugie D, Endebu M, Hailu D, Lema A. Screening of *Oreochromis niloticus* strains for their important production traits in high stocking density and low CP feed quality without aerating devices in concrete Tanks, Batu, Oromia, Ethiopia. Int J Fisheries and Aquatic Res. 2017;2(6):7-10.
3. Balkew K, Gjoen HM. Comparative studies on the growth performance of four juvenile *Oreochromis niloticus* L., (1758) strains in pond culture, Ethiopia. Int J Aquaculture. 2012;2(7):40-7.
4. Tugie D, Endebu M, Negisho T. Comparative study of growth performance of three *Oreochromis niloticus* populations under culture condition in concrete tanks, Zeway, Ethiopia. 2014;pp: 161-78
5. Ayenew T. Natural lakes of Ethiopia. Addis Ababa University Press. 2009; p. 206.
6. LFDP, Lake Fishery Development Plan. Lake management plans. Lake fisheries development project, phase II: Ministry of Agriculture, Addis Ababa, Ethiopia. 1997; pp: 49.
7. Dejene Z. Impact of fisheries and water quality changes on the management of Lake Chamo. 2008.
8. Tesfaye G, Wolff M. Stock assessment of fishery target species in Lake Koka, Ethiopia. Revista Rev Biol Trop. 2015;63(3):755-70.
9. Endebu M, Lema A, Genet T, Mitike A, Regassa B, Dejen E, et al. Fisheries baseline survey describing status of fisheries in Lake Zeway, Ethiopia. Fisheries Livest Prod. 2015;3(2):129.
10. Lemma B, Desta H. Review of the natural conditions and anthropogenic threats to the Ethiopian Rift Valley rivers and lakes. Lake Reserv Manag. 2016;21(2):133-51.
11. El-Zaeem SY, Ahmed MMM, Salama ME, El-Kader WN. Phylogenetic differentiation of wild and cultured Nile tilapia (*Oreochromis niloticus*) populations based on phenotype and genotype analysis. Afr J Agric Res. 2012; 7(19):2946-54.
12. Hailemichael A. Spatio-temporal analysis of Ethiopian rift valley Lake Chamo watershed utilization practices and environmental implications using geo-spatial technology. Department of Environmental Sciences, Andhra University, Viskhapatnam, India. PhD thesis. 2011. pp:143.
13. Kebede E, Mariam ZG, Ahlgren I. The Ethiopian Rift Valley lakes: chemical characteristics of a salinity-alkalinity series. Hydrobiologia. 1994;288(1):1-2.
14. Lagler KF. Freshwater fishery biology. 1956.
15. Tesfaye G. Population dynamics and stock assessment of Nile tilapia, *Oreochromis niloticus* L. in three Rift Valley Lakes (Koka, Ziway and Langano). 2006;pp:80.
16. Tesfaye G, Tadesse Z. Length-weight relationship, Fulton's condition factor and size at first maturity of tilapia, *Oreochromis niloticus* L. in Lakes Koka, Ziway and Langano (Ethiopian rift valley). Ethiop. J. Biol. Sci. 2008;7(2):139-57.
17. Tadesse Z. Studies on some aspects of the biology of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Ziway, Ethiopia. 1988;pp: 78.
18. Teferi Y, Admasu D. Length-weight relationship, body condition and sex ratio of Tilapia (*Oreochromis niloticus* L.) in Lake Chamo, Ethiopia. Ethiop J Sci. 2002;25(1):19-26.
19. Robinson BW, Wilson DS. Experimentally induced morphological diversity in Trinidadian guppies (*Poecilia reticulata*). 1995;2(3): 294- 305.
20. Abera LH. Current Ecological Scenario of some Rift Valley Lakes of Ethiopia: A review. EC Agriculture. 2016; 3(1): 570-80.
21. Allendorf FW. Conservation biology of fishes. Conser Biol. 1988; 2: 145-148.

22. Seyoum S, Kornfield I. Taxonomic notes on the *Oreochromis niloticus* subspecies-complex (Pisces: Cichlidae), with a description of a new subspecies. Can. J. Zool. 1992; 70: 2161-5.
23. Agnese JF, Adepo-Gourene B, Abban EK, Fermon Y. Genetic differentiation among natural populations of the Nile tilapia *Oreochromis niloticus* (Teleostei, Cichilidae). Heredity.1997;79: 88-96.