International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG (USA) Volume 8, Issue 3 -2021

Research Article

DOI: http://dx.doi.org/10.22192/ijarbs.2021.08.03.005

Assessment of *in situ* conservation of *Labeobarbus ethiopicus* in Lake Ziway

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Abstract

The physico-chemical parameters of the Lake Ziway seem to be threatened by anthropogenic and climatic factors, which in turn affect biotic factors as reflected in fish catch. A study was made to assess *in situ* conservation of *Labeobarbus ethiopicus* in Lake Ziway. Based on the assessment of fish composition of the lake, best site was selected for *in situ* conservation. Canonical Correspondence Analysis (CCA) showed that the average abundance of *C. carpio*, *C. carassius* and *C. gariepinus* were positively correlated with nutrients, whereas the abundance of *L. ethiopicus* and *Labeobarbus intermedius* had negative correlation with most of the physico-chemical variables. Hence, the analysis show that *Labeobarbus* species relatively preferred that high dissolved oxygen and clear water. Fishes were sampled monthly with different mesh size of gillnets and a total of 1242 fish specimens were recorded. *Labeobarbus ethiopicus* was the dominant fish species from the Family Cyprinidae next to *B. paludinosus* and *L. intermedius* that accounts to 20 %. *Carassius carassius* and *C.carpio* were almost equally represented in the catch with 11 % and 10 %, respectively in the *in situ* conservation area. The relationship between length and total weight of the fish was curvilinear and length-weight coefficient describes isometric growth. Therefore, sustainable utilization and conservation measures should be taken in and around the lake for sustainable conservation of the endangered fish species in particular and the lake ecosystem in general.

Keywords: *Conservation, fish composition, gill net, Labeobarbus ethiopicus, Lake Ziway,*

1. Introduction

Aquatic organisms are fundamental components in the ecological processes of shallow lakes [22]. The functions of these organisms in lake ecosystems is related to their species composition, distribution and abundance which in turn depend on various environmental factors such as light, water temperature, substrate composition, disturbances and quality of the lake water [12,28,15]. Hence, fishes provide ecosystem services in the form of supplying food to community that are also essential for ecosystem function and resilience. These regulating services include top-down effects regulating population dynamics and nutrient availability in or near sediments [10].

The relationship between environmental factors and the distribution of organisms within aquatic environments has received considerable attention. Fishes are one of the dominant macro faunal components of aquatic biota, and most studies have focused on their distribution patterns [11]. The relative importance of each factor differs according to the species and knowledge of aquatic habitat use by fishes, which is important for the improvement of conservation policies with a view to preserving ecologically importance.

Ethiopia has a number of lakes and rivers with substantial quantity of fish stocks. There are 10 major lakes with a total area of 7,400 km^2 and a combined length of 7,185 km of major rivers [9]. Many artificial water bodies have also been stocked with fish for fishery. Most of the lakes are located in the Ethiopian Rift Valley, which is part of the Great East African Rift Valley system.

The natural resource of the Rift Valley has immense economic and cultural values. These lakes are considered as centers of biodiversity, corridors of countless migratory birds; and are used in ameliorating the effects of drought and protein shortage for the population in the region [29]. Lake Ziway is one of the lakes in the rift valley used for multiple purposes like irrigation, fishing, domestic water supply, transportation, recreation and supply of fresh water to Lake Abijata through the out flowing of Bulbula River. Although its importance is in the wide range of purposes, the fishery resources are not utilized appropriately for the proper management of the lake.

There are seven indigenous fish species in the lake comprising *Barbus paludinosus, Garra dembecha, Garra makiensis, Labeobarbus ethiopicus,* Labeobarbus *intermedius, Labeobarbus microterolepis* and *Oreochromis niloticus* (Golubtsov *et al.,* 2002; Abebe, 2009). The lake also harbors five exotic fish species (*Tilapia zillii, Cyprinus carpio, Carassius carassius* and *Carassius auratus)* which were introduced to enhance its production, and *Clarias gariepinus* that slipped into the lake accidentally [14,1]. Therefore, the lake has several important fish species for fisheries.

Of those indigenous fish species, *Labeobarbus ethiopicus* was reported as endemic fish to the lake and currently the fish reported in “Red list category with Criteria of A” [1]. Since, freshwater ecosystems have been subjected to various environmental and human induced changes throughout the globe for centuries [3] and they are the most endangered ecosystems in the world. The changes associated with environmental degradation range from loss of biodiversity to complete loss of ecosystems[8,26] . In recent years, the establishments of increasing human populations as well as intense agricultural practices in catchments have resulted in significant degradation and loss of pristine ecosystems. Interventions in fisheries management so as to meet the increasing demand for fish has resulted in overexploitation particularly the commercially important fish species including *L. ethiopicus* [17]. Hence, the objective of this study is therefore, to assess some biology and composition of the fish with *in situ* conservation.

2. Materials and Methods

Description of study area

Lake Ziway belongs to the Central Ethiopian Rift (Figure 1). It is the third largest lake in the Ethiopian part of the Rift Valley and fourth in the country in terms of surface area. It lies in a shallow down-faulted basin [13] flanked in the east by a large basalt field with sandy or rocky shores [23].

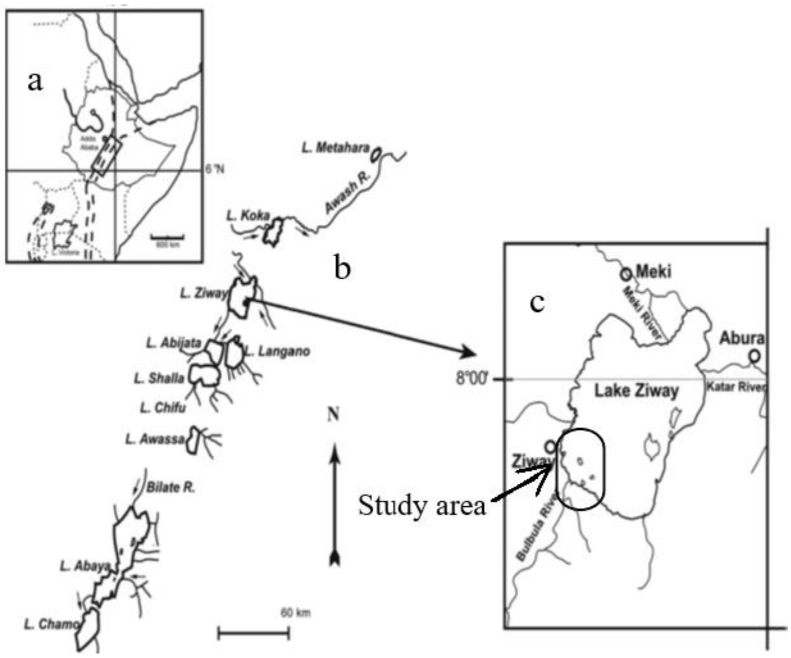

Figure1. **(a)** Location of Ethiopia in the Horn of Africa, **(b)** Location of Ethiopian Rift Valley Lakes and **(c)** Lake Ziway

Lake Ziway is bordered by two administrative zones of Oromia Regional State. The Western part belongs to East Shoa Zone while the Eastern part belongs to Arsi Zone (Fig. 1). The Western shore is shared by two districts, namely, Adami Tullu Jiddo Kombolcha (A. T. J. Kombolcha) and Dugda. The Eastern shore belongs to only Ziway Dugda (Z. Dugda) district. On the average, the lake is located at an elevation of 1650 meter above sea *level* at $7^{0}89'$ - $8^{0}05'$ N latitude and $38^{0}72'$ - $38^{0}92'$ E longitude located at about 163 km south of Addis Ababa. The lake is shallow and has an open water area of 434 km^2 and shoreline length of 137 km[27] . The maximum length and width of the lake is 32 km and 20 km, respectively [18].

There are two main feeder rivers to L. Ziway; namely, Meki originating from Gurage Mountains in the north-west and Ketar from the Arsi Mountains in the east; and it has one outflow in the south through Bulbula River, draining into Lake Abijata (Fig. 1).

Establishment of fishery management committee and training

Ziway-Batu Fishermen Cooperative was purposively selected for the activity. The members of the cooperative was fifty-eight. Training was given for the selected cooperative members on Lake Fishery management in general and *in situ* conservation practices of the fish in particular from the beginning of the activity through ongoing process.

In addition, the fisheries management committee were established from the fishermen and other stakeholders directly related to the sector. The approach was like co-management approach, where responsibility was shared between the government and other stakeholders, which harness the knowledge and capacities of those who have a shared interest in the sustainability of a fishery towards promoting the common end. The approach is therefore the response to manage fisheries and enforce regulations and responds to the desire to empower fishing communities.

Site selection

Before starting regular sampling program, a reconnaissance survey was conducted to fix the sampling sites and then *in situ* conservation area (Fig. 2). Hence, six sampling sites were selected based on geographical proximity and/or habitat similarity (river mouths neighboring floodplains, depth and distance to shore), their distance from human settlements and anthropogenic effect.

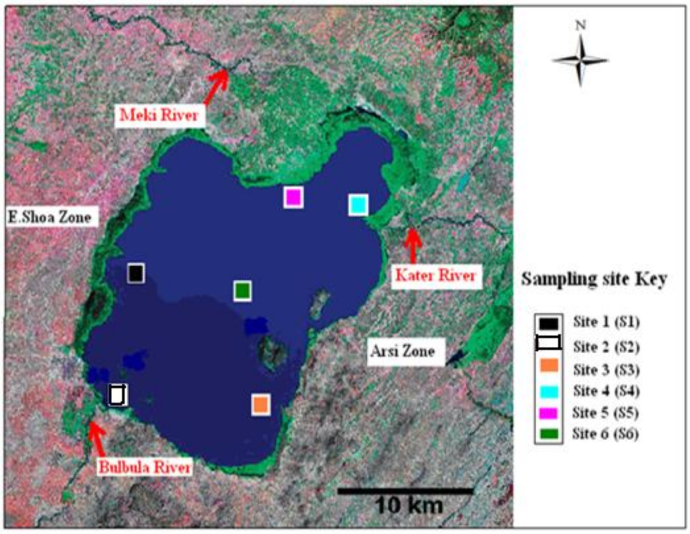

Figure 2. Lake Ziway satellite image with sampling sites

Global Positioning System (GPS) was taken to demarcate the locations of the study area, which are presented in Table 1. This type of categorization is helpful to note the detail characteristics of the study area. Again best site was reselect for *in situ* consecration of the fish based on better *L. ethiopicus* species composition as compare to others.

Table 1. Some characteristics of the sampling sites

Location of the study site		**Relative location**	**Designation**
Latitude	Longitude		
$07^0$54.79' N	$038^0$144.111'E	Western part of the lake	Site 1 (S1)
$07^0$54. 054' N	038^0 144.13'E	Southern part (around Bulbula River mouth)	Site 2 (S2)
$07^0$55' N	$038^0$52.086'E	Eastern part of the lake	Site 3 (S3)
$08^0$05. 379' N	038^0 56.459'E	Northern part (Ketar River mouth)	Site 4 (S4)
$08^0$04. 6000' N	038^0 53.509'E	Northern part (Meki River mouth)	Site 5 (S5)
$07^0$55. 49' N	038^0 52.934'E	Center of the lake	Site 6 (S6)

Site 1: The site is located in the western part of the lake and the shoreline is characterized by intensive cultivation with horticulture and field crops including flower farm. The sampling site was far from Ziway town, the flower farm and spots of horticulture cultivation (on the average about within a distance of at 0.5 to 7 km offshore at depths of 1.5 to 2.9 meter). The vegetation cover around the shoreline is degraded.

Site 2: The site is located around the river mouth of Bulbula in the area between two islands (Debresina and Funduro). The sampling site was distantly away from the shore of the lake on average about within a distance of 4.5 to 5 km at a depth of between 3 to 3.5 meter and the vegetation cover around the islands is almost conserved by different forest trees. The bottom of the site was full of rock.

Site 3: It is located on eastern part of the lake in Z.Dugda district in between Yerera (shoreline of the lake) and Tulu Gudo Island. The sampling site was distantly away from the shore of the lake on average about within a distance of 1.5 to 5 km at a depth of between 1.5 to 3.10 meter and the vegetation cover around the shoreline is almost conserved woodland.

Site 4: It is located around the river mouth of Ketar with a distance of 1.5 km from the tip of the mouth of Ketar River. As is the case with the other sites, the area is also characterized as moderately cultivated; however, the vegetation cover is relatively denser with shrub and marshland. The depth was between 1.5 to 3.20 m. The riverbed is mostly composed of mud and gravel.

Site 5: The site is located at the northern part of the lake and characterized by high human interference with horticulture and field crop activities next to site one. The sampling site was far away from Meki town, and the horticulture activities are within a distance of 0.5 to 5 km and the water depth was 1.5 to 2.9 meter.

Site 6: It is located almost at the center of the lake at a depth of 3.2 to 4.8 meters. The site was characterized by the activities of some fishermen using gillnets and long-lines.

Sampling and *in situ* conservation methods

The main elements that involved in developing a strategy for *in situ* conservation was ecogeographical surveys including assessment of water nutrients, fish diversity and management and monitoring of *in-situ* conservation areas.

Physico-chemical parameters

Physico-chemical parameters of the water were measured monthly from each site in 2018/19. Temperature, pH and conductivity of the lake were measured *in situ* during sampling periods at each sampling site. Temperature and pH were measured using a portable digital pH meter (Hanna 9024) and conductivity was measured using conductivity meter (Elmetron-model of CC411). Transparency was measured with a Secchi disc of 20 cm diameter. Depth was also recorded at each sampling station. Water samples were collected from each site in dark plastic bottles, washed with acid and rinsed with distilled water several times in duplicates for nutrient analysis. Water samples for Chlorophyll-*a* determination were taken by the Schindler sampler from all sites. These samples were transported on ice to the laboratory.

Nitrate was measured with sodium salicylate method, ammonium with indo-phenol blue and soluble reactive phosphate (SRP) with ascorbic method [5]. Nitrite concentration was determined by the reaction between sulfanilamide and N-naphthyl-(1)-ethylendiamin-dihydrochloride.

Fish parameters

Parallel to the physico-chemical sampling, every sampling period fishing was conducted using variety of fishing gears, which included gill nets of various mesh sizes (6, 8, 10 and 12 cm stretched mesh size), monofilament nets with various stretched mesh sizes (5 mm to 55 mm stretched mesh size). The gears were set in the afternoon (4:00 pm) and were collected in the following day (7:00 am). Immediately after capture, total length (TL) and total weight (TW) of the fish was measured to the nearest 1cm and 1g, respectively.

The relationship between total length and total weight of *L. ethiopicus* was calculated using least squares regression analysis (Bagenal and Tesch, 1978) as follows:

$TW = aTL^b$, for fork length,

Where: TW - Total weight in grams
TL - Total length in centimeters
a - Intercept of the regression line
b - Slope of the regression line

Data analysis

Prior to conducting Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA) was employed to check the response of the species data matrix (dependent set) to the environmental data matrix (independent set) using CANOCO for windows 4.5 version software followed by Pearson’s correlation in order to explain the relationships between biological assemblages of species and the environmental variables using PAST software. Therefore, CCA was used because the species data showed unimodal response to the environmental variables. According to [19], Redundancy analysis (RDA) or linear method should be used only if the length of the longest gradient is shorter than three. Redundancy analysis was also performed to observe the relation of species abundance data to environmental factors.

Species composition at each sampling station was presented as a numerical contribution by each species. This was determined by calculating the percentage of each species represented in the total catch for each site. Descriptive statistics were also used to analyze the remaining collected data using SPSS software [24].

3. Results and Discussion

Physico-chemical parameters in the study sites

The physico-chemical parameters of the lake water at the sampling sites markedly differ (Table 2). Site 4 (Around Ketar River mouth) and Site 5 (Around Meki River mouth) were different from other sites and were characterized by having higher dissolved oxygen and less Secchi depth (Table 2). Site 1 (Western part of the lake) was characterized by having higher nitrate, nitrite and conductivity. Site 2 (around Bulbula River) and Site 3 (Eastern part of the lake) were again characterized by having high level of Chl-*a* and temperature (Table 2).

Table 2. Mean and standard error values of physico-chemical variables of the study sites

Parameters	Sites					
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Temperature (^{0}C)	23.46±0.5	24.11±0.6	23.65±0.7	20.78±0.4	22.29±0.7	23.93±0.1
Secchi depth (cm)	19.98±0.7	22.12±0.9	21.4±0.5	18.79±0.2	17.85±0.3	21.58±0.7
Nitrite (µg/L)	40.38±0.7	30.67±0.2	23.57±0.2	30.81±0.4	30.03±0.3	18.62±0.2
Nitrate (µg/L)	61.66±10.6	44.41±5.5	42.81±2.6	30.1±4.7	52.32±9.5	33.01±14.1
Ammonium (µg/L)	124.55±1.1	112.6±8.8	130.3±4.7	64.17±11.9	258.92±9.4	125.23±0.3
SRP (µg/L)	59.19±36.3	50.34±3.9	64.73±4.7	43.75±24.5	42.64±4.1	38.2±19.1
Dissolved Oxygen(mg/l)	3.46±0.1	3.76±0.1	4.15±0.3	6.01±0.5	5.71±0.6	4.39±0.6
Chl- *a* (µg/L)	50±0.9	54.5±2.3	49±8.9	42.5±7.9	37±6.4	44.5±5.3
pH	8.03±0.2	8.23±0.1	8.3±1.3	8.29±0.3	8.09±0.1	8.37±0.1
Conductivity (⌠S/cm)	484.51±15.3	396.6±5.7	361.5±9.7	376.95±23	404.8±25.9	366.7±1.9

Daytime temperature of the studied sites ranged from 20.78 ^{0}C to 24.11 ^{0}C whereas pH ranged from 8.03 to 8.37. Dissolved oxygen varied from 3.46 to 6.01 mg/l. Low dissolved oxygen was measured at sites categorized as heavily impacted sites. Conductivity varied from 361.50 to 484.51 µS/cm. Soluble Reactive Phosphate varied from 38.20 to 64.73 µg/l and nitrite ranged from 18.62 to 40.38 µg/l. Relatively an extremely high value of nitrate 61.66 µg/l was recorded in the western part of the lake (S1). Ammonium ranged from 64.17 to 258.92 µg/l and the mean values of Chl-*a* ranged from 37 to 54.50µg/l (Table 2). The minimum and maximum mean values of Sechi depth readings were between 17.85 to 22.12 cm and the detailed descriptions for each sampling site were given in Table 2.

Distribution and composition of fish species in the lake

A total of ten species of fishes in the Families Cyprinidae, Clariidae and Cichilidae were identified from the different sites in the lake (Table 3). The species were *B. paludinosus*, *C. carassius*, *C.carpio*, *G. dembecha*, *G. makiensis*, *L. ethiopicus* and *L. intermedius* from the Family Cyprinidae, *C. gariepinus* from the Family Clariidae and *O. niloticus* and *T. zillii* from the Family Cichilidae. The status (presence/absence) of the species from the sampling sites was provided in Table 3.

Table 3. Fish species identified from the study sites of Lake Ziway (Present (+), Absent (-))

Family	Fish species	Sampling Sites					
		S1	S2	S3	S4	S5	S6
Cyprinidae	*Barbus paludinosus*	+	+	+	+	+	+
	Carassius carassius	+	+	+	+	+	+
	Cyprinus carpio	+	+	+	+	+	+
	Garra dembecha	+	-	+	-	-	-
	Garra makiensis	+	-	+	+	-	-
	Labeobarbus ethiopicus	-	+	-	+	-	-
	Labeobarbus intermedius	+	+	+	+	+	+
Clariidae	*Clarias gariepinus*	+	+	+	+	+	+
Cichilidae	*Oreochromis niloticus*	+	+	+	+	+	+
	Tilapia zillii	+	-	+	+	+	-

At species level, *O. niloticus* was the dominant fish species from the Family Cichilidae as well as the whole species from the lake and it accounts to 27.88 % of the total catch. *Cyprinus carpio* was the second dominant species that accounts to 25.19 %. *Carassius carassius* and *C. gariepinus* were almost equally represented in the catch with 20.71 % and 20.51 %, respectively from the lake in general (Fig. 3). The remaining fishes were each less than 3% of the total catch of fishes encountered in the lake (Fig.3).

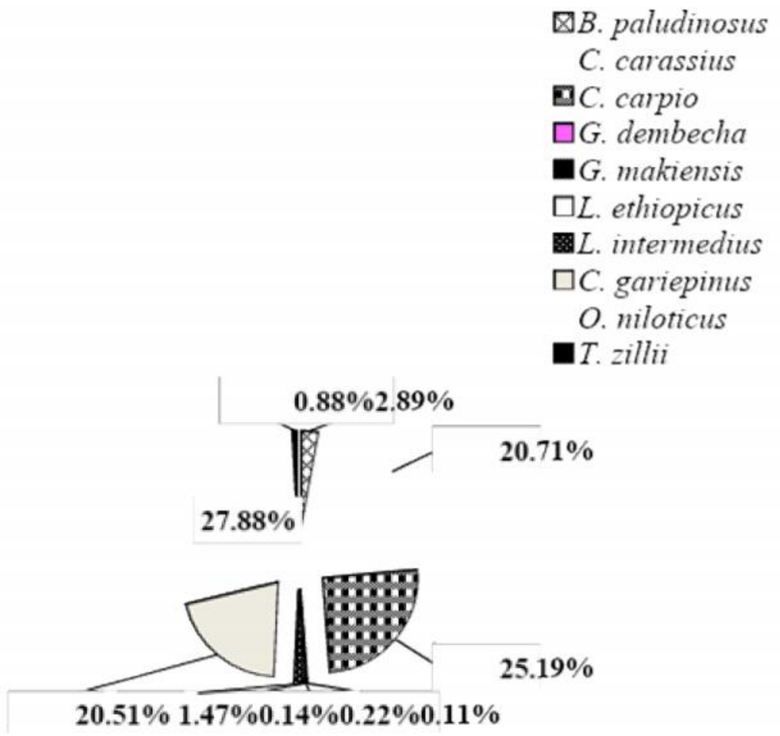

Figure 3. Composition of fish at species level in the lake (%)

Abundance of fish species in relation to environmental variables

The RDA ordination of the species-environmental association indicated that nitrate, conductivity, nitrite, SRP, Chl-*a*, temperature and pH were negatively correlated with the first axis. Secchi depth and dissolved oxygen were positively correlated to *L. ethiopicus* and *L. intermedius* with the the axis, which contributed 88.4% of this variance (Fig. 4 and Table 4). The remaining environment factors and fish species were negatively correlated with this axis (Fig.4 and Table 4).

Table 4. Result of redundancy analysis of abundance of the fishes and physico-chemical associations including eigenvalues and percentage variance explained by the first two axes, as well as the correlations between environmental variables and the axes (strong correlations are marked bold)

	Canonical coefficients	
Variables	**Axis 1**	**Axis 2**
Eigenvalues	0.884	0.093
Cumulative percentage variance of species-environment relation	0.884	0.977
Temperature	-0.0289.	-0.4912
Secchi depth	0.0263	**-0.7482**
Nitrate	**-0.5869**	0.3866
Nitrite	**-0.6302**	0.5450
Ammonium	0.1152	**0.5620**
SRP	**-0.9191**	-0.335
Dissolved Oxygen	0.3718	0.4955
Chlorophyll-*a*	-0.4406	-0.4658
pH	-0.0853	-0.4518
Conductivity	-0.4804	0.3651

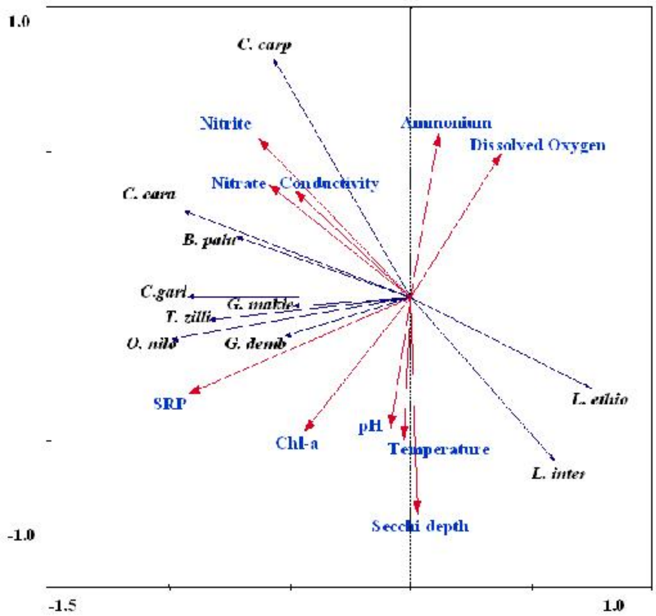

Figure 4. Biplots of the first two axes of correspondence analysis showing the association of fish species numerical abundance and environmental variables (Abbreviation: *L.ethio. - Labeobarbus ethiopicus, L.inter.- Labeobarbus intermedius, B.palu.- Barbus paludinosus, G.makie.-Garra makiensis, G.demb.- Garra dembecha, O.nilo.- Oreochromis niloticus, C.carp.-Cyprinus carpio, C.cara.- Carassius carassius* and *C.gari.- Clarias gariepinus* and SRP - Soluble Reactive Phosphate)

The second axis was positively correlated with the environmental variables nitrite, nitrate and conductivity that were associated with relatively high abundance of the two carp species (*C. carpio* and *C. carassius*) (Fig 4; Table 4). The remaining fish species (*O. niloticus*, *T. zillii*, *C. gariepinus* and the two *Garra* species) were negatively correlated with the two axes of the environmental variables such as Chl-*a*, SRP, pH and temperature.

Labeobarbus ethiopicus and *L.intermedius* preferred areas where there is high dissolved oxygen and relatively clear water (Fig. 4). According to Balakrishna *et al.* (2013), other chemicals and biological processes present in the water including temperature, influence oxygen availability throughout the year. Hence, the fishes were restricted to sites where there was relatively better oxygen availability.

Management practices of *in situ* conservation area

Based on the assessment of fish composition of the lake, site two was selected for *in situ* conservation practices due to better catch of *L. ethiopicus* as compare to other fish species (Fig.5). Since, the site had higher dissolved oxygen and relatively clear water than other site and owing lower value of Nitrate, Conductivity and Nitrite (Table 2), it is suitable for the production of the fish. The area was demarcated and closed from different activities like fishing during the study period.

Figure 5. Selected *in-situ* conservation area

Training of fishermen and other stakeholders

Fishermen and other stakeholders from district Agricultural offices were actively participated on the training of conservation practices of the particular fish species. Development agents, experts and fishermen were participated on the training given on fish production and management practices.

Table 5. Type of profession and number of participants on the training

Professionals	Participants		
	Male	Female	Total
Fishermen	55	1	56
DAs	1	-	1
experts	1	-	1
Total	57	1	58

Among the training participant stakeholders, 96.6 % were fishermen. From those fishermen, 1.8% was female (Table 5). Unlike the other economic activities where both male and female can engage, fishing activities was solely carried out by male due to the labor intensive nature of the work.

Different lake conservation and management materials were prepared for training. During the training, different questions, opinions and suggestion were raised and reacted from the concerned bodies. All fishermen were very interested to have the *in situ* conservation of *L. ethiopicus*. Therefore, all concerned bodies were shared their responsibilities for the intervention based on the proposed area of the lake.

Composition of fishes in *in situ* conservation area

Based on better catch composition of *L. ethiopicus in situ* conservation area was selected and demarcated. (Fig. 5 and 6).

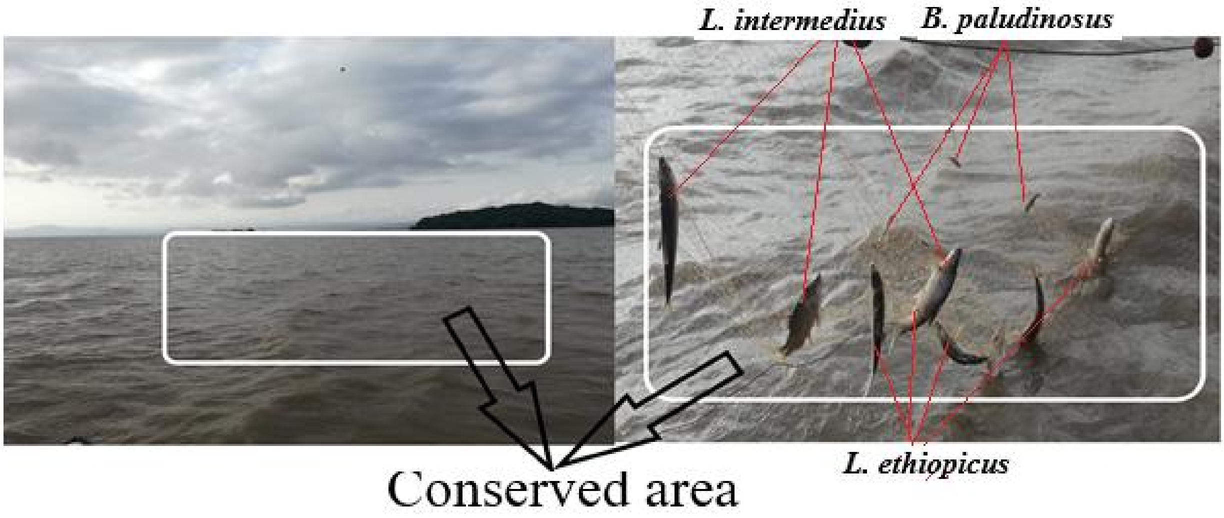

Figure 6. Composition of fish species during catch in the study area (%)

In the conservation area a total of 1,242 fish specimens were recorded from the three families during the study period. The species were *B. paludinosus*, *C. carassius*, *C. carpio*, *L. ethiopicus* and *L. intermedius* from the family Cyprinidae (83.98 %); *O. niloticus* from the family Cichilidae (6.2 %); and only *C. gariepinus* from the family Clariidae that accounts 9.82% (Fig. 7).

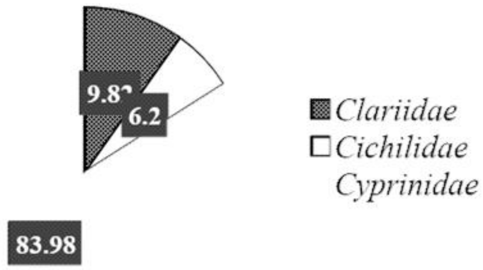

Figure 7. Composition of fish at family level in the conservation area (%)

At species level, *L. ethiopicus* was the dominant fish species from the Family Cyprinidae next to *B. paludinosus* and *L. intermedius* that accounts to 20 %. *Carassius carassius* and *C.carpio* were almost equally represented in the catch with 11 % and 10 %, respectively (Fig. 8). *Oreochromis niloticus* was accounts 2%, the least from the total catch of fishes encountered in the *in situ* conservation area of the lake (Fig. 8).

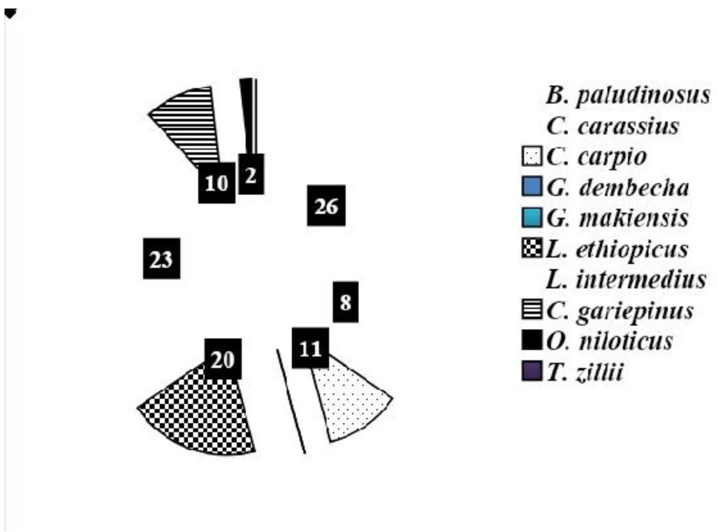

Figure 8. Fish species composition in the *in situ* conservation area (%)

In general, ten fish species have been recorded from the all sampling sites of the lake as described in figure 3, while *G. dembecha*, *G. makiensis* and *T. zillii* were not encountered in the conserved area. From the survey conducted in this study, before 35 years ago *L. ethiopicus* was encountered better catch in commercial fishery as that have been currently captured the dominant fish species, *C. carpio.*

Like that of this endangered fish, *Oreochromis niloticus* was the major species of the sample accounting for 94 % in previous studies (Schroder, 1984). However, the contribution of the fish has gradually declined to 89.3 % of total catch in 1994, 50.9 % in 2010 and 42 % in 2010 [20]; and 31 % in 2012 [16] and 27.88 % [17] due to different constraints.

Length-weight relationship of the fish

Length-weight relationship was determined for the fish and it was curvilinear and statistically highly significant ($P < 0.05$). The line fitted to the data was described by the regression equations shown in figure 9. An equation combined for fish ranging in length from 18 - 33 cm; and the corresponding total weight from 160 to 550 g for both sexes was fitted and shown in figure 9.

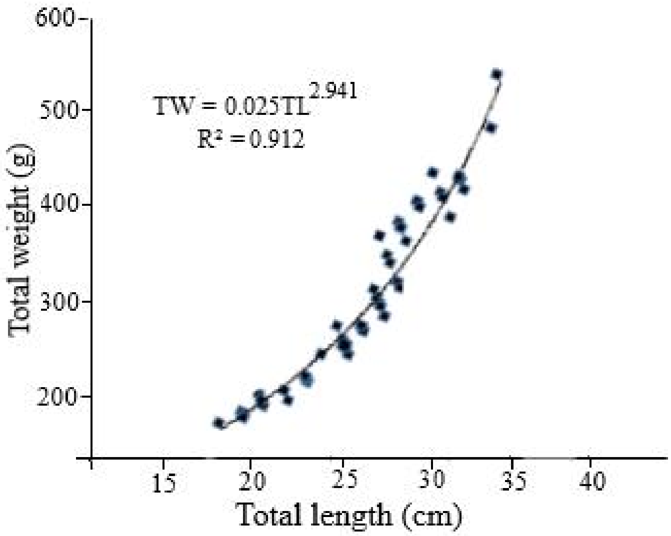

Figure 9. Length-weight relationship of *L. ethiopicus* in Lake Ziway.

The relationship between length and total weight of the fish was curvilinear (Fig. 9). In fish, a length weight coefficient (b) of 3 describes isometric growth, that is the fish retain the same shape and their specific gravity remains unchanged with growth in their life time [21]. The coefficient of *L. ethiopicus* in this study is in agreement with [6], and comparable to the value of b calculated for the same families of *L. intermedius* species in the same lake (2.8) [16].

4. Conclusions and Recommendations

Lake Ziway has shown some undesirable changes in terms of some physico-chemical factors and shift in catch composition of fish species. Soluble reactive phosphate and nitrate level of the lake increased in recent years. However, the nutrient level in the lake is still lower than that of most Ethiopian lake and the Secchi depth reading of the lake have also shown declining trend.

The fish fauna of Lake Ziway is dominated by Cyprinids. Of the total ten species recorded in the lake only seven species were sampled at *in situ* conservation area. Based on percentage composition, *L.ethiopicus* is relatively the most dominant fish next to *B. paludinosus* and *L. intermedius* in the conservation area, which contributed to 20 % of the total catch. Length-weight relationship of the fish was curvilinear and the growth of the fish was isometric growth.

Thus, appropriate management is an urgent need to address the contribution of the fishery as a source of food, income and employment as ongoing activity. This can be done either by the government or by the fishing communities themselves or by both and may follow the following recommendations.

- With increase in nutrients and inorganic turbidity and more degradation in the catchment, fish species composition may continue changing in the future. Therefore, monitoring of fishes and management of nutrient inputs should be carried out on regular basis. The lakeshore should be restored with macrophytes and protected in order to control external nutrient loading. The current practice of Batu Fish and Other Aquatic Life Research Center with community based planting of mutually beneficial legume plants, like *Sesbania sesban* as animal feed should be continued for better management of the lake.

- There are indications of severe degradations of the lake basins particularly the water shade areas. The most threats to the lake are related to deforestation, irrigation and overgrazing by domestic animals in the lake basin. Therefore, sustainable utilization and conservation measures should be taken in and around the lake for sustainable conservation of the endangered fish species in particular and the lake ecosystem in general.

- In Lake Ziway, large number of small sized fish of all species are being exploited and proper management actions are required to protect the immature fish. Particularly, capture size of the stock should be determined taking into consideration the size at first maturity of fishes. Therefore, the fishery management plan such as prohibiting fishing on spawning ground during the breeding season is needed for the lake before the fishery resource is overexploited. In addition, high dependence on fishing activity has posed a serious threat to the fish resource. Thus, management tools like closed area and seasons, catch quota restriction, mesh size regulations, gear restrictions and limits on the number of fishers has to be for sustainable exploitation of the stocks.

- Need to implement the existing regional as well as national fishery proclamation.

- Regular monitoring of the lake's limnology and fishery is needed in order to understand the trends of the lake.

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DOI:10.22192/ijarbs.2021.08.03.005	

How to cite this article:
Lemma Abera Hirpo. (2021). Assessment of *in situ* conservation of *Labeobarbus ethiopicus* in Lake Ziway. Int. J. Adv. Res. Biol. Sci. 8(3): 37-50.
DOI: http://dx.doi.org/10.22192/ijarbs.2021.08.03.005