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DIVERSITY, DISTRIBUTION AND ABUNDANCE OF FISH SPECIES IN LAKE LANGENO, ETHIOPIA

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ABSTRACT: This study of diversity, distribution and abundance of fishes in Lake Langeno (also written as Langano in the literature), Ethiopia, was conducted from March 2014 through February 2016. The basis for this study was that fish species were subject to uncontrolled fishing over many years and existing data on diversity has become unreliable for management and sustainability of the sector. In order to examine the existing diversity, habitat preference and seasonal distribution, spatial and temporal data were collected from six different sampling sites by using various mesh-sizes of gillnets and long lines. Data were analyzed by Canonical Correspondence Analysis (CCA), SPSS software and also by various descriptive statistics. The results indicate that all the physico-chemical parameters did not show significant spatial, but high temporal variations. A total of seven fish species dominated by cyprinid family were identified (H′ = 1.264). *Carassius carassius* and *Cyprinus carpio*, which were not reported in previous studies, now comprise 0.64% and 6.99% of the total collected specimens, respectively. All the fish species were collected from all the sampling sites, except at the middle site where *C. carassius* and *Garra dembecha* were absent. IRI was essentially similar for all the sampling sites, but differed in the relative importance of each species with the high importance of *Oreochromis niloticus*. Principal component analysis (PCA) did not produce distinct habitat-associated species patterns across the sampling sites. However, temperature and depth seemed to be the key environmental factors determining fish community structure in the lake. The results showed that the composition of the fishes has undergone some changes from what was reported in the literature. Therefore, appropriate management action is required in order to sustain the resources for conservation and continued fishing practices.

Key words/phrases: Diversity, Ethiopia, Fish abundance, Fish distribution, Lake Langeno.

INTRODUCTION

Fishery is one of the important production sectors, which play a key role in the economy of many nations and fishes serve as the diet of many poor people in the world (Tacon and Metian, 2009). However, environmental

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changes due to human activities and some natural factors like climate change have been causing adverse effects on fishery resources (Mohammed and Uraguchi, 2013). Moreover, human activities such as overexploitation, habitat alteration, pollution from industrial and agricultural discharges, and introduction of exotic fish species are highly contributing to the declining level of aquatic biodiversity both in freshwater and marine environments (Leveque *et al*., 2008).

Studies of fish species composition and their spatial and/or temporal distribution are useful to examine factors influencing the structure of fish communities (Galactos *et al*., 2004). This is because fish species diversity is influenced both by biotic and abiotic processes that function across various scales of space and time. Mainly, diversity and distribution of freshwater fish species is highly influenced by the types of river basin (Tesfaye Wudneh, 1998; Vijverberg *et al*., 2012), physical factors (temperature, depth, topography, water current and physical barrier) and chemical properties of water (Leveque *et al*., 2008). In addition, various biological factors such as availability of food, breeding sites, density, competition, predation and composition of aquatic plants in each habitat influence the diversity and distribution of fish species (Harris, 1995).

Conservation of aquatic biodiversity is based on the knowledge of fish stock and their distribution, because site-specific management is based on the knowledge of fish community difference per site and water body (Vijverberg *et al*., 2012). Thus, knowledge of fish diversity, distribution, stock sizes and the means of exploitation should have to be known for each water body (Sileshi Ashine, 2013). In addition, assessing the fish biodiversity and their interaction with biotic and abiotic factors would give a broader understanding of the functions and ecological values of these ecosystems (Blay *et al*., 2011).

Ethiopia has a large spectrum variety of freshwater fish biodiversity, but except for some lakes, fish communities were rarely studied in a quantitative way (Vijverberg *et al*., 2012; Tadlo Awoke, 2015). The studies show that there is a reduction in species diversity from northern and central highlands to the rift valley lakes, which vary from 40 to 85% (Abebe Getahun and Stiassny, 1998). Additionally, the Ethiopian rift valley contains a system of small to medium-sized lakes, some of which are saline (Gashaw Tesfaye, 2011; Tadlo Awoke, 2015).

Lake Langeno is one of the Ethiopian rift valley lakes having fish species of considerable diversity (Vijverberg *et al*., 2012). The commercial catch in central Ethiopian rift valley is mainly harvested from Lake Zeway and Langeno (Mathewos Hailu *et al*., 2010). Lemma Abera (2012 unpublished data) and Vijverberg *et al*. (2012) did a preliminary research on fish biodiversity assessment in Lake Langeno. However, still there is no complete data on fish biodiversity and their distribution across spatial and temporal scales with respect to physico-chemical parameters of the lake. Therefore, this study aimed at assessing diversity, distribution and relative abundance of fish species in Lake Langeno, Ethiopia.

MATERIALS AND METHODS

Description of the study area

Lake Langeno is one of the Ethiopian rift valley lakes located in Oromiya Regional State, between Western Arsi zone and East Shoa zonal Administration at 200 km from Addis Ababa toward the south. It is enclosed by Arsi Negelle district from south, west and east, and by Adami Tullu Giddo Kombolcha district from the north, between 7°36′N and 38°43′E at an altitude of 1,585 m above sea level. The lake is considerably deep with a maximum depth of 70 m and an average depth of 17 m. It covers about 240 km^2 of land. The eastern part of the lake is surrounded by eastern Langeno nature reserves. It is mainly fed by hot springs and rivers originating from the highlands of Arsi Mountains, such as Lepis, Gedemso, Garabula, Metti, Tufa and Sedesedi Rivers, but it is only drained by Hora-Kelo River that joins Lake Abijata (Mathewos Hailu *et al*., 2010). The inflow water volume from these rivers and hot springs is estimated to be about 533.4 million m^3 and outflow is about 527.9 million m^3 per year (Tenalem Ayenew, 2004).

The water chemistry of the lake is similar to the other lakes in Ethiopian rift valley where Na^+ and CO_3^{2-} are the dominant cation and anion, respectively. The mean conductivity of the lake is about 1 632 μScm^{-1}. Salinity of the lake is also high about 9.4 (mg/L) (Zinabu Gebremariam *et al*., 2002). The lake serves as a home to many of animal and plant diversities. Dense phytoplankton blooms, mainly Cyanophytes, characterize the lake. However, the phytoplankton biomass (1.6 mg/L) and productivity (Chl *a*: 2 µg/L) of the lake is very low (Kassahun Wodajo and Amha Belay, 1984). According to Kassahun Wodajo and Amha Belay (1984), the zooplankton assemblage is dominated by Cladocera and *Copepoda* spp. Most people of the area (34%) are engaged in fishing for their livelihood. Tilapia is a major fish caught for market and food, and is cooked freshly on the campfire for visitors, but even though Lake Langeno serves as a site of tourism, there is no sport fishing (unpublished data, Lemma Abera, 2012).

Study design and sampling site selection

The study was conducted from March 2014 to February 2016. Based on the population of the fishermen in the area, distance from the shore, depth of the lake, distance from the road and human activity in the catchment area, six sampling sites were selected (one site from the middle and five sites from shore areas) for the collection of appropriate data. Morphometric variables of the lake, which includes average and maximum depth, were measured both in wet and dry season by labeled rope tied with weight at each sampling site. Global Positioning System (GPS) was taken to demarcate the locations of the sampling sites (Table 1).

Table 1. Geographic Positioning System (GPS) record of the different sampling sites and their descriptions in Lake Langeno, Ethiopia.

Site	Average Depth (m)	Latitude & longitude	Relative location in the lake	Distinctive characteristics of the site
Hora-Kelo	8.7	7°39'13.7"N 38°43'37.9"E	North-western part	Visited by large number of fishermen next to Dole site, presence of outlet river here, the site is protected by wetlands and there is agricultural farm lands beyond the site
Hoitu	10.2	7°38'40.4"N 38°46'17.4"E	Northern part	Supporting high number of fishermen with majority of them fully licensed, two hot springs are feeding the site, outer part of the site does not support agriculture
Tufa	12.3	7°35'02.3"N 38°48'21.0"E	Eastern part	The 4th in supporting a large number of fishermen, most of the fishermen fishing from this site are not legally licensed, no agriculture at the outer part of the lake by this side and have many inlet tributaries
Wabishebele	19.7	7°36'44.0"N 38°43'13.2"E	Western part	This site is serving as a tourism center, there are many farm lands beyond the site, is supporting less fishermen
Middle	43.5	7°35'24.4"N 38°45'40.3"E	Middle part	This site is supporting only few fishing activities than all and far away from human activities
Dole	11.5	7°32'23.1"N 38°44'17.5"E	Southern part	This site is visited by large number of fishermen next to Hoitu, the southern shores are protected by wetlands, beyond which farm lands are found, presence of one inlet tributary

Collection and measurement of physico-chemical parameters

At each sampling site, depth integrated water samples were collected monthly from one depth at shore area and from three depths (surface, middle and near the bottom depending on the total depth of the specific site) at offshore sites by tube sampler (Bartram and Balance, 1996). The collection of water samples and measurement of physico-chemical parameters were done between 09:30 and 13:30 am. Measurements of pH, temperature, electrical conductivity, dissolved oxygen and water transparency were done *in situ* (Table 2). For chlorophyll *a* content analysis, pre-treatment and filtration were carried out immediately in the field by Whatman filter paper with No. 42 µm mesh size. The filters were folded in, dabbed between 2 pieces of blotting paper, and wrapped with aluminum foil to avoid light. The samples were frozen at <-4°C and transported to the Limnology laboratory at Addis Ababa University for further analysis.

Table 2. Instruments used for physico-chemical parameters measurement in Lake Langeno, Ethiopia.

No.	Parameters	Determination method and instruments
1	Secchi depth	30 cm diameter of Secchi disk
2	Dissolved oxygen	Dissolved Oxygen Metre (PN# DK0600)
3	Temperature	Conductivity metre (HANNA pH211)
4	pH	Digital pH metre (Hanna 9024)
5	Total dissolved solids	Conductivity metre (HANNA pH211)
6	Electrical conductivity	Conductivity metre (HANNA pH211)
7	Chlorophyll-*a*	Spectrophotometer (APHA, AWWA and WPCF, 1998)

Fish sampling method

From the six selected sites, fish samples were collected for two years. Because of the gear-specific selectivity associated with fish size, species and sampling location, varied mesh sizes of gillnets (6 cm, 8 cm, 10 cm and 12 cm) with 25 m panel length and 1.5 m depth were used to capture representative samples of fishes (Vijverberg *et al*., 2012). In addition, long lines with number 9 and 11 hook sizes were used to catch the large-sized fish species. At depths more than 10 m, two nets were used; one net at the top and one at the bottom. The bottom nets were set between 10 and 15 m. Nets were set at approximately 2 hours before sunset, left to sample overnight and catches were collected the following morning two hours after sunrise (Imam *et al*., 2010). The numbers of fish caught were recorded for each sampling occasion. Total length (mm) and total weight (g) of fish were immediately measured by using measuring board to the nearest 0.1 cm and OKI balance with sensitivity of 0.1 g. The fish samples were placed in plastic jars containing 10% formalin, labeled, and transported to Zeway Fishery Resources Research Centre for further analysis.

Laboratory study

The specimens were soaked in tap water to wash off the formalin. After a few days, the specimens were transferred to 75% ethanol before species identification was conducted. Then, the captured fishes were identified to species and genera levels at the Zeway Fishery Resources Research Centre laboratory based on Golubtsov *et al*. (1995), Okaronon *et al*. (1998) and Redeat Habteselassie (2012). Chlorophyll *a* analysis was also done spectrophotometrically according to Bos (2008).

Data analysis

All of the physico-chemical data were log transformed (log x+1). One-way analysis of variance (ANOVA) was used to compare fish species diversity, distribution and abundance in different sites of the lake. The number of fish caught per season was also compared by one-way ANOVA. CANOCO 4.5 was used to run canonical correspondence analysis (CCA). CCA was used to investigate the association of fish species distributions with the environmental variables. In addition, Shannon Diversity Index (H′) was used to evaluate the diversity of fish species in the lake (Shannon and Weaver, 1963). H′ explains both variety and the relative abundance of fish species.

$H' = -\sum P_i \ln P_i$

Where: - H′ = diversity index

$P_i = n_i/N$ = number of individuals within species (n_i)

N = total number of individuals (N)

An Index of Relative Importance (IRI) was also calculated to measure the relative abundance of fishes based on number and weight of individuals in catch, and their frequency of occurrence (Kolding, 1989). This was calculated as:

$$\%IRI_i = \frac{(\%W_i + \%N_i) X \%F_i X 100}{\sum_{j-1}^{s-1} (\%W_j + \%N_j) X \%F_j}$$

Where: %Wi = percentage weight of each fish of total catch

%Ni = number of each species of total catch

%Fi = percentage of frequency of occurrence of each species in total number of settings

%Wj = percentage weight of total species of total catch

%Nj = number of total species of total catch

%Fj = percentage frequency of occurrence of total species in total number of settings

S = total number of species

RESULTS

Physico-chemical parameters of Lake Langeno

The average Secchi depth, dissolved oxygen (DO), water temperature, pH, TDS, electrical conductivity and chlorophyll a content recorded from Lake Langeno are presented in Table3.

Table 3. The physico-chemical parameters obtained from different sampling sites of Lake Langeno, Ethiopia.

Site	Secchi (cm)	DO (mg/L)	Temp (°C)	pH	TDS (mg/L)	Conductivity (µS/cm)	Chlorophyll *a* (µg/ L)
Hora-kelo	15.5 ± 2.3	5.1 ± 0.8	23.5 ± 1.2	9.46 ± 0.1	1526.0 ± 156.0	1785.0 ± 98.0	6.4 ± 0.5
Hoitu	15.9 ± 2.1	5.0 ± 0.9	23.8 ± 1.3	9.44 ± 0.4	1510.4 ± 161.6	1796.8 ± 98.2	6.2 ± 0.3
Tufa	15.9 ± 2.2	5.5 ± 0.9	23.4 ± 1.2	9.45 ± 0.1	1498.8 ± 131.2	1772.7 ± 95.4	6.3 ± 0.4
Wabishebele	15.4 ± 1.9	5.2 ± 1.2	23.6 ± 1.2	9.48 ± 0.1	1534.13 ± 77.5	1791.4 ± 108.1	6.4 ± 0.6
Middle	15.8 ± 2.8	5.2 ± 1.2	23.5 ± 1.2	9.43 ± 0.1	1486.2 ± 145.9	1767.1 ± 93.6	6.2 ± 0.3
Dole	15.7 ± 2.3	5.1 ± 0.9	23.4 ± 1.1	9.46 ± 0.2	1522.2 ± 149.1	1779.1 ± 92.4	6.4 ± 0.3
Total mean	15.7 ± 0.2	5.2 ± 0.2	23.5 ± 0.2	9.45 ± 0.01	1510.3 ± 18.9	1781.4 ± 12.5	6.3 ± 0.1
p-value	0.93	0.91	0.96	0.42	0.86	0.29	0.43

DO= Dissolved oxygen, Temp. =Temperature, TDS=Total dissolved solids

The Secchi depth of the study area ranged from 11.5 cm in July to 21.2 cm in February with the mean depth of 15.7 cm. The minimum DO concentration was recorded in February (4.8 mg/L), and the maximum result was recorded in August (7.2 mg/L) with the mean DO content of 5.18 mg/L. The minimum water temperature was recorded in August (20.8°C), and maximum temperature was recorded in February (25.6°C) with the mean temperature of 23.54°C. The minimum (9.41) and maximum (9.64) pH values were recorded in July and February, respectively with the mean pH of 9.45. Total dissolved solids (TSD) of the lake was also found in a range between 1417.5 mg/L in February and 1644.5 mg/L in July with the mean TDS of 1512.99 mg/L. In addition, the electrical conductivity (EC) of the water was found in a range between 1543 and 1889 µS/cm with the mean EC of 1782.05 µS/cm. Finally, the mean chlorophyll *a* content of the lake was 6.31 µg/L where low chlorophyll *a* content was recorded in February (6.02 µg/L), and high chlorophyll *a* content was recorded in July (6.54 µg/

L). The result indicated a significant variation among the study months for all parameters (ANOVA, P<0.05), but no significant variation was observed for all parameters among the study sites (ANOVA, P>0.05).

Diversity of fish species in Lake Langeno

A total of 4,207 fish specimens (1,950 males and 2,257 females) belonging to seven species categorized under three families (Cyprinidae, Cichlidae and Clariidae) were collected from the lake. Family Cyprinidae composed of five species made 55% of the catch, followed by family Cichlidae dominated the fish community. *Barbus paludinosus* (40.69%) was the most dominant species by number followed by *O. niloticus* (39.41%). Nevertheless, *C. carassius* and *G. dembecha* were the least abundant in the catch (Table 4).

Table 4. The fish species composition in Lake Langeno, Ethiopia.

Family	**Fish species**	**No. of individuals**			**Percentage (%)**
		Male	**Female**	**Total**	
Cyprinidae	*B. paludinosus*	765	947	1712	40.69
	L. intermedius	127	129	256	6.09
	C. carpio	138	156	294	6.99
	G. dembecha	13	15	28	0.67
	C. carassius	17	10	27	0.64
Cichlidae	*O. niloticus*	778	880	1658	39.41
Clariidae	*C. gariepinus*	112	120	232	5.51
Total		1950	2257	4207	100

Diversity indices of fish species in Lake Langeno

Summarized values of Shannon-Weiner Diversity Index (SWDI) of fish species in the lake are provided in Table 5. The values of SWDI ranged from 1.001 to 1.345. Comparatively, the northern (Site Tufa) and southern part (Site Dole) of the lake had the highest SWDI among the sampling sites. However, the values of SWDI did not show significant variation among the sites (ANOVA, p=0.984).

Table 5. Diversity index of fishes in Lake Langeno, Ethiopia.

Site	**Total**	**H'**	**$\chi 2$**
Hora-Kelo	679	1.278	1.25
Hoitu	689	1.331	1.41
Tufa	969	1.346	1.32
Wabishebele	655	1.282	1.26
Middle	379	1.001	2.18
Dole	836	1.345	1.32
Total	4207	1.264	1.29

H'=Diversity index, $\chi 2$= chi-square values (significant at P<0.05)

Distribution of fish species in relation to environmental variables

The first two axes of CCA explained 91.3% of the species-environment variance (Table 6). The CCA ordination of the species-environment association indicated that temperature, TDS, conductivity and pH were positively correlated with the first axis (Fig. 1).

Table 6. Summary of the CCA result obtained for the relationship between physico-chemical parameters and fish distribution in Lake Langeno, Ethiopia.

Parameters	Axis 1	Axis 2
Eigen values	0.036	0.006
Cumulative percentage variance of species environment relation	78.2	91.3
Secchi disc	-0.3080	0.3987
DO	-0.6893	0.4947
Temp	0.4610	-0.1862
pH	0.0692	-0.7107
TDS	0.5931	-0.7268
Conductivity	0.1544	-0.8409
Chlorophyll *a*	-0.2661	-0.5893

DO = Dissolved oxygen, Temp. = Temperature, TDS = Total dissolved solids

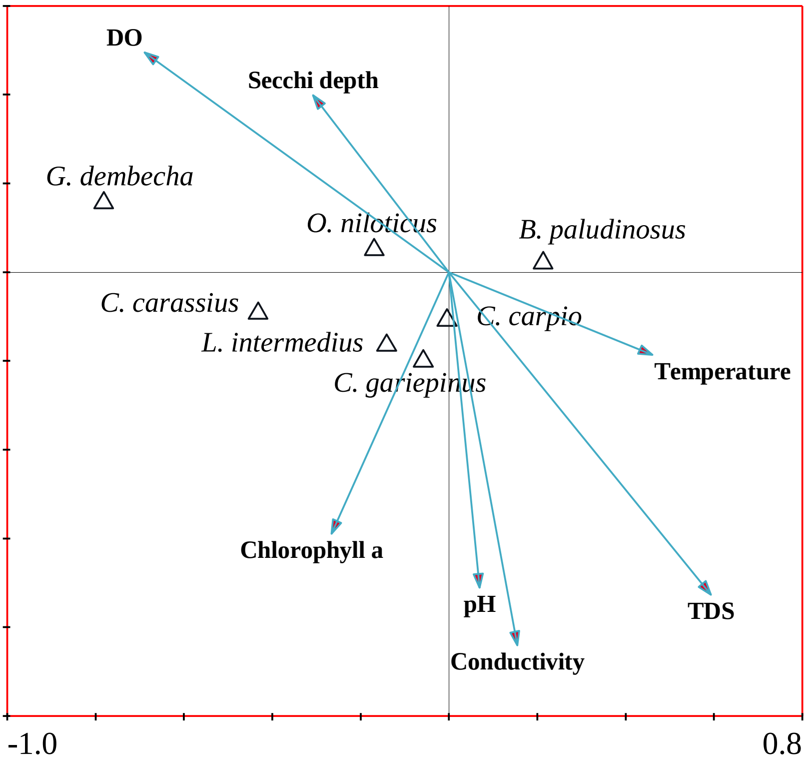

Fig. 1. Cannonical Correspondance Aanalysis (CCA) of the relationship between physico-chemical parameters and fish species distribution in Lake Langano, Ethiopia.

The distribution of *B. paludinosus* population had positively correlated with temperature, TDS, electrical conductivity and pH of the water. However, the relationship was very weak except for temperature. In other words, all the other fish species had positive relationship with DO, chlorophyll *a* content and secchi depth. Except for water temperature, the relationship between species and environmental variables were very weak.

The second axis which showed 13.1% of variance was positively correlated with environmental variables like DO and Secchi depth which were directly associated positively with the high abundance of *O. niloticus*, *B. paludinosus* and *G. dembecha*. Other environmental variables like chlorophyll *a*, pH, conductivity and TDS were negatively correlated with the second axis and fish species. These were particularly negatively correlated with chlorophyll *a* content.

Spatial variation and relative abundance of fish communities in Lake Langeno

The composition of fish species from all sampling sites were also ranked based on the index of their relative importance (Table 7).

The catches from Site Tufa contributed the highest individual frequency (23.03%) followed by Site Dole (19.87%), but small number of fish catches were collected from the Site Middle (9.01%). The result showed that *B. paludinosus* was the most abundant fish species in the lake. It was most abundant at Site Hora-Kelo (19.39%) followed by Site Wabishebele (17.69%). *Oreochromis niloticus* was the other most abundant fish species next to *B. paludinosus* at all sampling sites. The high abundance of *O. niloticus* was observed at Site Tufa (29.25%) followed by Site Dole (21.77%). *Clarias gariepinus* was the highest at Site Tufa (22.84%) followed by Site Wabishebele (22.41%). *Labeobarbus intermedius* was more abundant at Site Hoitu followed by Site Tufa. High abundance of *C. carpio* was observed at Site Hora-Kelo followed by Site Dole. However, there was no significant variation in fish abundance among the sites (ANOVA, $P<0.05$).

Table 7. Percentage of IRI of different fish species in different sites of Lake Langeno, Ethiopia.

Site	Fish species	N	%N	W	%W	F	%F	IRI	%IRI
Hora-Kelo	*O. niloticus*	209	30.78	21.80	23.24	23	100.00	5402.46	27.81
	B. paludinosus	332	48.90	0.94	1.00	23	100.00	4989.85	25.69
	C. gariepinus	34	5.01	27.44	29.26	22	95.65	3277.31	16.87
	L. intermedius	42	6.19	12.65	13.49	22	95.65	1881.60	9.69
	C. carpio	58	8.54	29.75	31.72	22	95.65	3850.73	19.82
	C. carassius	3	0.44	1.21	1.29	3	13.04	22.53	0.12
	G. dembecha	1	0.15	0.01	0.01	1	4.35	0.69	0.004
	Total	679	100.00	93.79	100.00			19425.17	100.00
Hoitu	*O. niloticus*	249	36.14	25.72	27.98	23	100.00	6412.37	33.71
	B. paludinosus	294	42.67	0.83	0.91	23	100.00	4357.69	22.91
	C. gariepinus	35	5.08	21.49	23.38	21	91.30	2598.51	13.66
	L. intermedius	48	6.97	18.84	20.50	21	91.30	2507.87	13.18
	C. carpio	50	7.26	22.16	24.11	22	95.65	3000.05	15.77
	C. carassius	7	1.02	2.81	3.06	7	30.43	124.05	0.65
	G. dembecha	6	0.87	0.06	0.06	6	26.09	24.32	0.13
	Total	689	100.00	91.92	100.00		0.00	19024.86	100.00
Tufa	*O. niloticus*	485	50.05	40.32	30.11	23	100.00	8015.87	40.69
	B. paludinosus	280	28.90	0.79	0.59	23	100.00	2948.83	14.97
	C. gariepinus	53	5.47	34.18	25.52	23	100.00	3099.27	15.73
	L. intermedius	62	6.40	24.54	18.33	23	100.00	2472.40	12.55
	C. carpio	64	6.60	29.92	22.34	23	100.00	2894.77	14.69
	C. carassius	10	1.03	4.02	3.00	10	43.48	175.33	0.89
	G. dembecha	15	1.55	0.14	0.11	13	56.52	93.61	0.48
	Total	969	100.00	133.91	100.00		0.00	19700.07	100.00
Wabishebele	*O. niloticus*	221	33.74	23.75	27.38	23	100.00	6112.22	31.06
	B. paludinosus	303	46.26	0.86	0.99	23	100.00	4724.93	24.01
	C. gariepinus	52	7.94	33.13	38.19	23	100.00	4613.13	23.44
	L. intermedius	34	5.19	9.45	10.90	22	95.65	1538.79	7.82

Site	Fish species	N	%N	W	%W	F	%F	IRI	%IRI
	C. carpio	42	6.41	18.74	21.60	22	95.65	2679.72	13.62
	C. carassius	2	0.31	0.80	0.93	2	8.70	10.71	0.054
	G. dembecha	1	0.15	0.01	0.01	1	4.35	0.71	0.004
	Total	655	100.00	86.75	100.00		0.00	19680.20	100.00
Middle	*O. niloticus*	133	35.09	15.42	43.18	23	100.00	7826.77	45.78
	B. paludinosus	212	55.94	0.60	1.68	23	100.00	5762.11	33.70
	C. gariepinus	18	4.75	9.97	27.90	17	73.91	2413.08	14.11
	L. intermedius	8	2.11	4.71	13.19	8	34.78	532.11	3.11
	C. carpio	8	2.11	5.02	14.05	8	34.78	562.28	3.29
	C. carassius	0	0.00	0.00	0.00	2	0.00	0.00	0
	G. dembecha	0	0.00	0.00	0.00	1	0.00	0.00	0
	Total	379	100.00	35.72	100.00		0.00	17096.35	100.00
Dole	*O. niloticus*	361	43.18	41.13	32.30	23	100.00	7548.47	38.19
	B. paludinosus	291	34.81	0.82	0.65	23	100.00	3545.55	17.94
	C. gariepinus	50	5.98	33.81	26.56	23	100.00	3253.64	16.46
	L. intermedius	62	7.42	18.86	14.81	23	100.00	2223.04	11.25
	C. carpio	62	7.42	30.24	23.76	23	100.00	3117.29	15.77
	C. carassius	6	0.72	2.41	1.89	6	26.09	68.12	0.34
	G. dembecha	4	0.48	0.04	0.03	4	17.39	8.85	0.045
	Total	836	100.00	127.31	100.00		0.00	19764.97	100.00

N=total number, W=Total weight, F=Frequency of occurrence, IRI- Index of relative importance

Temporal variation of fish communities in Lake Langeno

All of the fish species were collected in all of the sampling periods. However, high number of catch was observed in June to October (Fig. 2).

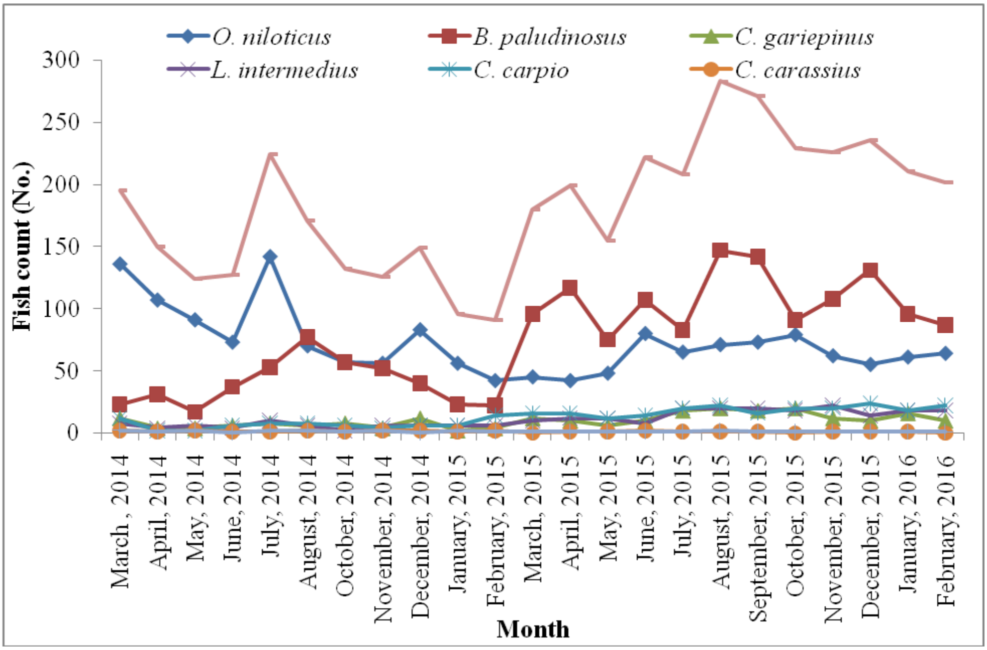

Fig. 2. Temporal changes of different fish species catch in Lake Langeno.

The result showed a significant variation of catch among the sampling periods (P<0.05). The catch of *O. niloticus* decreased from year one to year two; however, the catch of *C. gariepinus*, *C. carpio* and *L. intermedius* increased while that of *C. carassius* and *G. dembecha* did not show any variation. High number of *O. niloticus* specimens was collected in March and July 2014. Similarly, high number of *B. paludinosus* was collected in August and September 2016. Generally, high number of fish specimens was collected in August and September 2016, whereas, it was very small in January and February 2014.

DISCUSSION

Physico-chemical parameters of Lake Langeno

Fish naturally tend to select the habitat that is most suitable for their physiological requirements. Particularly, the physico-chemical properties of the water can affect the distribution of fish species in aquatic environment (Reash and Pigg, 1990). There are considerable variations between fish species in their tolerance range to these variations of water parameters.

In the present study, the result obtained for Secchi depth showed a seasonal fluctuation, which was strongly associated with the rainy season of the study area (Barroso *et al*., 2005). The Secchi depth of the lake is very low as compared to the report from Lake Zeway (Girma Tilahun and Ahlgren, 2010; Lemma Abera, 2016), Hawassa (Admasu Woldesenbet, 2015), Chamo (Adane Fenta and Almaz Kidanemariam, 2016), Tana (Essayas Kaba *et al*., 2014), Hashengie (Tsegay Teame *et al*., 2016a) and Koka Reservoir (Elizabeth Kebede, 1996) and in some rivers of Abbay basin (Dereje Tewabe *et al*., 2016) which shows that the lake is very turbid. This could be due to silt and clay accumulation, which are known to form a stable colloidal suspension in Lake Langeno (Amha Belay and Wood, 1984).

The mean DO content of this study (5.18 mg/L) is comparable with that of Lake Zeway (3.46 to 6.01 mg/L) (Lemma Abera, 2016) and Lake Tana (6.71 to 7.78 mg/L) (Shewit Gebremedhin *et al*., 2014). However, it was less than that of Elizabeth Kebede (1996) in Koka reservoir (5−11.37 mg/L), Brook Lemma (2003) in Lake Haramaya (6.0−10.0 mg/L), Dereje Tewabe *et al*. (2010) in Tekeze and Abay basins (6.25 to 9.9 mg/L), Admasu Woldesenbet (2015) in Lake Hawassa (11.2−20.55 mg/L) and Adane Fenta and Almaz Kidanemariam (2016) in Lake Chamo (10.26−17.42 mg/L). This is because dissolved oxygen concentrations depend on topography and depth of water (Langland and Cronin, 2003).

The mean water temperature of the present study (23.54°C) is comparable with the water temperature reported from Lake Zeway (Lemma Abera, 2016), but it is greater than the findings in Lake Hawassa (Begashaw Abate *et al*., 2015), Hashangie (Tsegay Teame *et al*., 2016a), and Haramaya and Hora-Kilole (Brook Lemma, 2003). However, it is less than the report in Lake Chamo (Adane Fenta and Almaz Kidanemariam, 2016) and Tekeze reservoir (Dereje Tewabe *et al*., 2010). The studies show that the fluctuation in water temperature causes the changing of metabolic activities of fish, which results in the variation in species distribution (Adane Fenta and Almaz Kidanemariam, 2016).

The mean pH of our finding (9.45) showed slight variation from the previous report of Zinabu Gebre-Mariam *et al*. (2002) (8.91) in the same study area. It is also greater than the pH report in Lake Zeway (8.84 to 8.66) (Girma Tilahun and Ahlgren, 2010), Hawassa (6.98 to 7.59) (Begashaw Abate *et al*., 2015), Abaya (7.85 to 9.0) (Zinabu Gebre-Mariam *et al*., 2002), Chamo (8.45 to 9.02) (Adane Fenta and Almaz Kidanemariam, 2016), Tana (6.69 to 7.48) (Shewit Gebremedhin *et al*., 2014) and in Koka reservoir (8.11 to 8.6) (Elizabeth Kebede, 1996). However, it is less than the report in Zinabu Gebre-Mariam *et al*. (2002) in Abijata (9.5−10.3) and Shalla (9.4−10.2) lakes. High value of pH shows the high consumption of free CO_2 by alga, which results in decreasing of H^+ concentration, which influences the distribution of the aquatic organisms (Adane Fenta and Almaz Kidanemariam, 2016).

The result of TDS in our study (1,512.99 mg/L) is greater than the finding of Berhanu Rabo (2008) in Lake Zeway (270 mg/L), Admasu Woldesenbet (2015) in Lake Hawassa (455.6 mg/L) and Adane Fenta and Almaz Kidanemariam (2016) in Lake Chamo (656 mg/L). The concentration of TDS in natural waters is determined by the geology of the drainage basin, atmospheric precipitation and the water balance. It may also result from anthropogenic activities and effluents from the environment and industrial effluent, changes of the water balance or by salt-water intrusion of the water (Weber-Scannell and Duffy, 2007). The mean electrical conductivity (EC) of the present study (1,782.05 µS/ cm) also showed a slight increment as compared to the report of Zinabu Gebre-Mariam *et al*. (2002) in the same study area (1,632 µS/ cm). It is also very high as compared to the findings in Lake Zeway (Lemma Abera, 2016), Chamo (Zinabu Gebre-Mariam *et al*., 2002), Hawassa (Admasu Woldesenbet, 2015) and Koka reservoir (Zinabu Gebre-Mariam *et al*., 2002). However, the result indicated the lowest EC measurement as compared to the finding in Lake Abijata (Tamiru Alemayehu *et al*., 2006) (19,000 to 23,000 µS cm^{-1}) and in Lake Hora, Hashangie, Arenguade, Tillo, Shalla, Abijata and Mechafera (2,166, 2,350, 6,240, 10,590, 23,004, 26,008, 33,700 µS cm^{-1}, respectively) (Zinabu Gebre-Mariam *et al*., 2002).

Diversity of fish species in Lake Langeno

Family Cyprinidae was the most dominant in terms of diversity and abundance (contributed 55% of the catch) which is similar to the findings elsewhere in Ethiopia (Vijverberg *et al*., 2012; Tadlo Awoke, 2015; Lemma Abera, 2016). Lemma Abera (2012, unpublished data) and Vijverberg *et al*. (2012) reported three and five fish species, respectively, in the same study area. *Cyprinus carpio* and *Carassius carassius* were not mentioned in their reports, but *C*. *carpio* is now the third most dominant catch in this study. The difference could be due to the difference in the fishing gear types used and the time in which the specimens were collected (Sayeed *et al*., 2014).

Barbus paludinosus was the most dominant fish species in this study, which contradicts with the previous reports of Lemma Abera (2012, unpublished data) and Vijverberg *et al*. (2012) who reported *O. niloticus* as the dominant fish species. This could probably be due to a change (natural or anthropogenic) that induced the abundance of *B. paludinosus*.

The H′ value of the present study (7 spp: H′ = 1.001 to 1.345) is less than H′ value reported in Lake Zeway (9 spp: H′ = 1.5127 to 1.6681) (Lemma Abera, 2016), Blue Nile river (8 spp: H′ = 1.23 to 1.64) (Tadlo Awoke *et al*., 2015) and Lake Victoria Basin, Kenya (11 spp.: H′ = 1.359 to 1.545) (Mwangi *et al*., 2012). This indicated that Lake Langeno is comparatively the poorest in its ichthyo-faunal diversity. The number of fish species recorded in the lake is also very small as compared to the reports in Lake Tana (Dereje Tewabe, 2014), southern rift valley lakes (Vijverberg *et al*., 2012), Tekeze reservoir (Tsegay Teame *et al*., 2016b) and Baro basin (Golubtsov and Darkov, 2008) which confirms the low fish diversities in the lake (Golubtsov and Mina, 2003; Vijverberg *et al*., 2012). The physical isolation of the lake from adjacent lakes might have caused the lower diversity of fishes (Tadlo Awoke, 2015). However, the result is comparable with that of Aloo *et al*. (2013) for Lake Naivasha and greater than that of Mulugeta Wakjira (2013) for Gilgel Gibe I Reservoir.

Distribution of fish species in relation to environmental variables

The Canonical Correspondence Analysis (CCA) of the present study indicated that *O. niloticus* and *G. dembecha* were found relatively in sites with high DO (Fig. 1). According to Abdel-Tawwab *et al*. (2014), growth of Nile tilapia can significantly be retarded at low level of dissolved oxygen. High temperature, TDS, conductivity and pH of the water were slightly associated with the highest abundance of *B. paludinosus* in the lake. Similarly, Aloo *et al*. (2013) stated that *B. paludinosus* which was initially only found at the north swamp and around the river mouth of Malewa was increasingly becoming more abundant with the increase in water temperature. In other words, *C. carassius, C. carpio, C. gariepinus* and *L. intermedius* were directly related to relatively high chlorophyll *a* content. Our finding is in agreement with that of Lemma Abera (2016) in Lake Zeway except for *L. intermedius*. However, the correlations of all fish species distribution with the environmental variables were not very strong except for *B. paludinosus*, which is strongly associated with water temperature. Perhaps, water depth could be the responsible factor for the distribution of fish species in the present study. This is because dissolved oxygen concentrations decreased with increasing water depth (Ali *et al*., 2013).

Spatial variation and relative abundance of fish species in Lake Langeno

In this study, similar fish species were caught in all sampling sites except at the middle site in which *G. dembecha* and *C. carassius* were absent (Table 7). This might be due to the deep depth of this site, which extended up to 70 m. The littoral zone is often considered as the most important habitat for fishes. This is because the structural complexities of the littoral zone provides a more diversified food resources and serve as breeding ground for many of fish species (Benson and Magnuson, 1992). Shannon Weaver Diversity index (SWDI) confirmed that there was no significant species segregation among the sampling sites, which showed that all of fish species are adapted to live in all of the sampling sites (Table 5). The absence of significant heterogeneity among sites could be corroborated with their similarity in physico-chemical conditions.

Oreochromis niloticus and *Barbus paludinosus* were the most abundant fish species at all sampling sites (Table 7). This shows a good correlation of these species with overall environmental factors of the area. Mulugeta Wakjira (2013), Lemma Abera (2016) and Tsegay Teame *et al*. (2016a) also reported the dominance of *O. niloticus* at all landing sites in Gilgel Gibe I reservoir, in Lake Zeway and Tekeze reservoir, respectively. High abundance of *B. paludinosus* was also reported in Lake Zeway (Lemma Abera, 2016). However, *G. dembecha* and *C. carassius* were the least abundant fish species at all sampling sites. The genus *Garra* is apparently highly tolerant and largely found in streams that hardly flow (Abebe Getahun and Stiassny, 1998). Additionally, *C. carassius* prefer to live and reproduce in shallow ponds, lakes rich in vegetation and slow moving rivers (Lorenzoni *et al*., 2007). Therefore, the absence of vegetation cover and high depth of the lake could be the factors for the scarcity of this fish species in the lake. In general, fish diversity was higher in Tufa site followed by Dole site. This could be due to their shallowness and they have certain wetland coverage, which is very important for their persistence and reproduction (Graff and Middleton, 2001).

Temporal variation of fish species in Lake Langeno

The results showed that almost similar fish species were collected during the entire sampling period with the highest number of catches in wet season (June to October) (Fig. 2). This is in agreement with the findings in Lake Zeway (Lemma Abera, 2016), Lake Tana (Dereje Tewabe, 2014) and Omo-Turkana River System (Mulugeta Wakjira, 2016). According to Jackson and Harvey (1997), different fish species exhibit variation in the space they occupy over time. Moreover, biotic and abiotic factors, and seasonal changing of habitat may cause the seasonal variations in ichthyofaunal distribution. In addition, seasonal changing of fishermen's participation may determine the seasonal changing of fish distribution (Lemma Abera, 2016). Most people were involved in fishing as their primary work during dry season due to the absence of rainfall for other agricultural activities and high demand of fish in the market (Assefa Mitike, 2014).

Our results showed that the total number of fish caught showed a slight change during the data collection. The catch number of *O. niloticus* was highly reduced in the second year, whereas the catch number of other species especially *B. paludinosus*, *C. carpio*, *C. gariepinus* and *L. intermedius* were slightly increased. This could be due to the increasing of water temperature and number of fishermen in the second year due to the reduction of other agricultural activities, which led them to focus on some commercially important fish species like *O. niloticus* (Mohammed and Uraguchi, 2013). In addition, change in water temperature restricts the survival, growth and distribution of fish species, because it causes depletion of dissolved oxygen content. Therefore, fish species are believed to respond to environmental changes like a warming water temperature by shifting their behavioural and ecological changes (Tacon and Metian, 2009; Mohammed and Uraguchi, 2013). This could be the case in the present study, which may have led the very tolerant and resilient fish species to be dominant in the lake.

In conclusion, the fish diversity of the lake is very poor, and the species distribution does not show spatial variation, but a significant temporal variation was observed due to a combination of both human and natural factors. Thus, effective follow up and appropriate management is very important for the lake Langeno fisheries.

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