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Study on Physico-chemical Parameters in Relation to Species Composition and Abundance of Zooplankton and Water Quality of Rift Valley Lake Langano, Ethiopia

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ABSTRACT: The study aimed to assess concentration of some heavy metals and physico-chemical parameters in relation to water quality and zooplankton Lake Langano. The lake was sampled at four stations from January to July, 2016 concurrently with physico-chemical parameters, heavy metals concentration and zooplankton. The data was analyzed using descriptive statistics, ANOVA, canonical correspondence and biological indices. 21 zooplankton species with eight species of cladocera and four species of cyclopoid copepods were identified from the lake. The diversity index narrowly ranged from 0.39-0.77 spatially. The abundance of zooplankton was maximum during April month at all sites with statistically significant variation both temporally and spatially ($p<0.05$). The abundance and species composition of zooplankton of the lake was negatively correlated Zn, Cu, Cd, PO_4^{3-}, NO_3^-, conductivity and water temperature. A maximum (189. 05±32.05mg/l and 72.67±125.21mg/l) of concentration of Cd was measured temporally and spatially respectively and that exhibited temporal significant difference ($p < 0.05$). High (27.85 ± 4.97^{0}C) mean value of water temperature was measured at Simbo site that showed temporally significant variation ($p<0.05$). The maximum mean TDS, NO_3^- and PO_4^{3-} of Simbo site (855.29±42.67mg/l, 29.44±32.74mg/l and 0.40±0.67mg/l) and no statistically significantly varied spatially ($p>0.05$). Most of the concentration of physico-chemical parameters and heavy metal of the lake were above the permissible limits set by WHO and EPA. The study provided baseline information on some water chemistry and biota of the lake and their ecology of Lake Langano.

KEYWORDS: Abundance, Concentration, Heavy metals, Lake Langano, Physico-chemical parameters, Zooplankton.

1 INTRODUCTION

Water is fundamental element to all forms of life and critical for sustainable development like environmental integrity, alleviation of poverty and hunger and indispensable for human well-being. It's commonly used as solvent, drinking water, cleaning purposes, irrigation, industrial uses, transportation, recreation and fish production (Olatunji *et al.,* 2012). The freshwaters are very productive at the primary, secondary and tertiary trophic levels. Water pollution on the other hand, decreases the water's usefulness ecologically, economically and aesthetically due to human population growth and industrial development (Adimasu, 2015). Aquatic environments are subject to high temporal variability, with frequent reorganization of composition and abundance of the inhabitants as a result of the interactions between physical, chemical and biological variables. In natural aquatic ecosystems the level of heavy metals, physical and chemical parameters occur in low concentrations from ng/l to few mg/l, however due to increasing loading the level of heavy metals, physical and chemical exceed in high concentration and they cause serious impairment in metabolic, physiological and structural systems of the inhabitants. Zooplanktons are very sensitive to accumulation of heavy metal, nutrient loading, acidification, contamination, fish densities and sediment inputs that provides as bioindicators (Akpor *et al.,* 2014; Mekuyie, 2014).

Ethiopia is rich country in inland water bodies, which owns twelve river basins, eleven fresh lakes, nine saline lakes, four carter lakes and over twelve wetlands. Currently almost of the water bodies of the country are polluted by untreated waste from agricultural activities, urbanization and industrialization, as result affects the water quality, composition and abundance of inhabitants at all life stages (Tilahun, 2006). It's therefore; imperative to assessing the concentration of heavy metals and physico-chemical parameters in relation to diversity and abundance of zooplankton community of Lake Langano for stability of water quality and environment assessment.

2 MATERIALS AND METHOD

Lake Langano is one of the northern rift valley lake of Ethiopia with slightly saline nature in Southeastern direction of the Addis Ababa city. It lies at geographical coordinates of 7^{0}30-7^{0}42'N and 38^{0}40-38^{0}49'E and an altitude of 1585m a.s.l. (Fig. 1). The lake is fed by rivers from the highlands on eastern escarpments of the lake and Southern from the Arsi Mountains and discharges from the northern end via River Horakolla to Lake Abijata to the south. The lake is highly turbid and the water is usually reddish brown color. The lake has a total surface area of 241km^2, maximum and mean depth of 47m and 17m respectively with small seasonal water level variations (1m). The water temperature of the lake ranges from 23-29^{0}C and pH of 9.1 (Dadi *et al.,* 2015). The lake was sampled at four sites namely Bushangari (macrophytes and fish), Hara Langano (riverine site), Simbo (transition zone) and Sabana (lacustrine zone) based on habitat type, human activities, presumption of high abundance of macrophytes and fish. At all sites sampling of heavy metal, zooplankton and physico-chemical variables were performed.

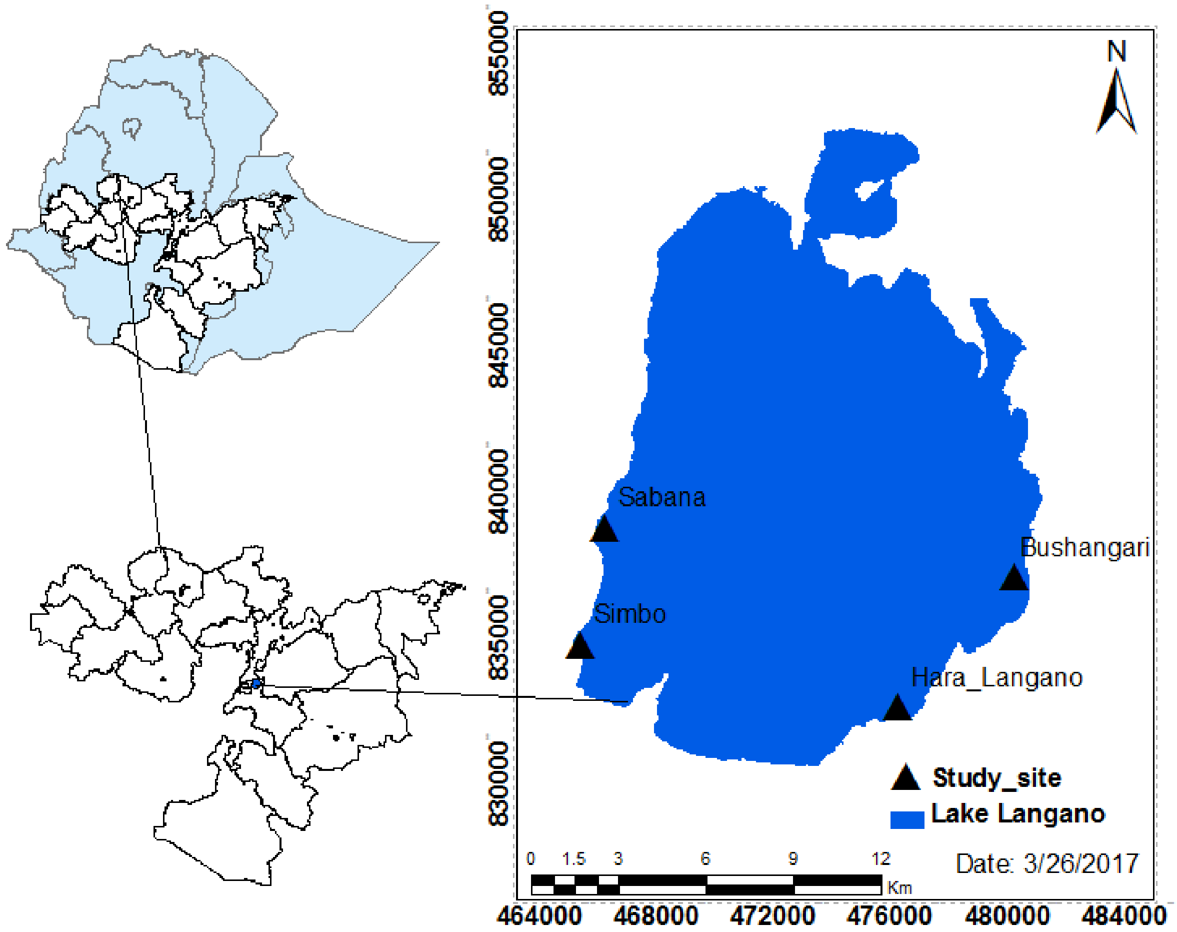

Fig. 1. Geographical location of the study area

SAMPLING AND IN SITU MEASUREMENTS

Field survey was conducted monthly from January to July, 2016. Water samples were collected for Cd, Cu, Zn, NO_3^-, PO_4^{3-} and zooplankton at 0.5m water depth for subsequent analysis at the laboratory. Water sample for determination of NO_3^- and PO_4^{3-} were taken using acid washed 500ml polyethylene bottels. Water samples for the analysis of Cd, Cu and Zn concentration were collected using acid washed 500ml amber-colored polyethylene bottels and immediately digested by 10% of HNO_3. Water samples for zooplankton were collected by plankton net 55µm mesh size and taken using acid washed 500ml polyethylene bottels and preserved by 4% formalin solution immediately. All the collected samples were transported to the laboratory with collecting ice box to protect samples from being autolysis and get accurate concentration, number and composition of zooplankton. Water temperature (^{0}C), total dissolved solids (mg/l), pH and electric conductivity (µS/cm) were measured in situ using Hanna multiprobe meter, whereas water transparency measured in situ using 20cm diameter Secchi depth.

SAMPLE ANALYSIS

The concentration of available zinc (Zn), copper (Cu) and cadmium (Cd) were determined triplicates by atomic absorption spectrophotometer (AASP-6800 Schimadzu) and air-acetylene flame followed by the method of Clesceri *et al.* (1998) and APHA (1998). The concentrations of heavy metals were calculated from the developed standard calibration curve and values were reported in mg/l. Metal concentration was calculated by the following formula:

$$Heavy\,metal\,concentration\,(\mathrm{mg/l}) = \frac{\mathrm{mg/l\,conc.\ observed\ \times final\,vol\,of\,sample\ in\ ml}}{\mathrm{Volume\ of\,sample\,taken\,in\,ml}} \quad (1)$$

Aliquots of 80ml were filtered from a homogenized sample with funnel filter paper for analysis of the concentration of NO_3^- and PO_4^{3-}. Concentration of NO_3^- and PO_4^{3-} were measured by Phenol disulphonic acid (PDA) and stannous chloride method respectively using an AASP at 410nm and 880nm wave length respectively. The concentration of NO_3^- and PO_4^{3-} were calculated from the developed standard calibration curve and values were reported in mg/l. Subsamples of 60ml were drawn from homogenized sample with a manual pipette of 4mm mouth diameter and transferred into petridish and counting chamber for identification and counting of zooplankton under dissecting microscope. Identification was done using standard taxonomic keys (Fernando, 2002; Witty, 2004) and counting was done carefully by rotating the petridish and counting chamber under the dissecting microscope. The abundances of zooplankton in the water samples were expressed as number of individual's m^{-3} (Clesceri *et al.,* 1998) as follows:

$$Abundance\,(m^{-3}) = \frac{Zooplankton\,/\,ml\,of\ conc.sample \times Volume\,of\ conc.sample\,(ml)}{Volume\,of\ water\ filtered} \quad (2)$$

STATISTICAL ANALYSIS

Two-Way ANOVA in SPPS (version 20) was used to infer significant variations in the concentration of heavy metals, physico-chemicals variables and abundance of zooplankton across sampling sites and study period. Canonical correspondence analysis (CCA) was performed in PAST (version 3.08) to measure the strength of correlation of abundance and composition of zooplankton to the physico-chemical variables and heavy metals. The Shannon-Weaver diversity index (H') was used as a measure of zooplankton diversity of the lake (Shannon and Weaver, 1963).

3 RESULT AND DISCUSSION

HEAVY METALS AND PHYSICO-CHEMICAL PARAMETERS

The spatial mean concentration of heavy metals and physico-chemical parameters of Lake Langano is given in Table 1. The mean concentration of Cd (6.49±3.75mg/l) and Cu (3.86±0.68mg/l) were high at Hara Langano site and low at Simbo and Sabana sites respectively ($p < 0.05$). Temporally the mean concentration of Cd and Cu statistically significant varied ($p = 0.003$ and $p = 0.00$) with high (16.85±1.63mg/l and 8.85±0.95mg/l) during the month of May respectively (Table 2). At Hara Langano site and during earlier rainy months the concentration of Cd and Cu were high, this could be attributable to inlet nature of the lake, sedimentation, discharging of soluble substance and civic wastes through run off from the surrounding medium, erosion of natural deposits, high dust entrance to lake from strong wind, use of agricultural fertilizers and high burning due to agricultural operation season (Olopade, 2013; Mekuyie, 2014; Patil *et al.*, 2014).

Table 1. Spatial means concentration of heavy metals and physico-chemical parameters of Lake Langano

Parameters	**Sites**			
	Bushangari	Hara Langano	Simbo	Sabana
Cd (mg/l)	6.07±3.05	6.49±3.75	3.69±1.11	5.89±0.45
Zn (mg/l)	1.59 ±0.04	0.56±0.07	3.24±0.51	2.48±1.05
Cu (mg/l)	3.09±0.31	3.86±0.68	3.04±0.98	3.03±0.11
Water transparency (m)	0.23±0.03	0.27±0.06	0.27±0.045	0.26±0.04
Water temperature (^{0}C)	26.3±1.24	27.24±2.03	27.85±4.97	27.22±3.44
pH	8.88±0.82	8.77±0.62	8.73±0.05	8.98±0.93
Conductivity (µS/cm)	1651.9±93.44	1714.0±47.86	1672.7±106.65	1694.4±69.67
TDS (mg/l)	827.0±46.93	848.71±39.69	855.29±42.67	853.29±27.69
NO_3^- (mg/l)	29.26±26.38	16.34±16.61	29.44±32.74	28.69±35.14
PO_4^{3-} (mg/l)	0.25±0.30	0.35±0.50	0.40±0.67	0.31±0.56

High Zn concentrations recorded during the rainy months at all sites (p = 0.14) (Table 2). Spatially Zn concentration varied, this associated with agricultural wastes through run off, high decomposition of plant matter and autochthonous inputs (Nazir *et al.,* 2015). Although high concentration of Zn affects the physiological, nervous and metabolic process of aquatic inhabitants, important for protein synthesis. The concentrations of Cd, Cu and Zn of Lake Langano (5.53mg/l, 3.25mg/l and1.97mg/l respectively) is above the acceptable ranges of the provisional discharge limits (0.1mg/l, 0.05mg/l and 0.1mg/l respectively) set by the EPA (2003) and WHO (2011) for dirking water and domestic uses. Heavy metal concentrations of the lake water were increased in the sequence of Zn > Cu > Cd (Table 1).

Water transparency and conductivity of Lake Langano was high at Hara Langano site (0.271±0.045m and 1714±47.86 µS/cm) and during none rainy months (February, January and March) of the study (Table 1 & 2), however statistically insignificant spatially (p > 0.05) and low mean value (0.22±0.02m and 1586.53±9.1µS/cm) was measured during the month of June and July respectively temporally (p = 0.23 and p =0.00) (Table 2). Low water transparency is associated with high temperature, turbidity, sediment inputs, high nutrients and increased production of plankton (Knight and Voth, 2012; Priyanka *et al.*, 2013). Lake Langano is classified as eutrophic lake (Zsd<2m), high NO_3^- concentration (>50mg/l) and high TDS (>500mg/l). Variation in the concentration of conductivity of the lake is ascribed with increased physical disturbances in the inlet of the lake and increasing the effect of water temperature on the viscosity of water related to ionic mobility (Embaye *et al.,* 2017). The conductivity of the lake (1683.21µS/cm) is above the permissible limit of drinking water (500µS/cm) recommend by WHO (2011).

Mean surface water temperature of the lake ranged from 26.3±1.24^{0}C at Bushangari to 27.85±4.97^{0}C at Simbo site. Water temperature showed statistical significant variation both temporally (p = 0.003) (Table 2) and spatially (p = 0.035) (Table 1), this could be associated with bright sunshine, high dry season temperature, soil type, high CO_2 emission and weak vertical mixing (Mohamed *et al.,* 2009) and could affect metabolic activities and oxygen consumption of aquatic organisms (Ahmed, 2003, Embaye *et al.,* 2017). The water temperature of Lake Langano (27.15^{0}C) was laid above the permissible limit (25^{0}C) of the EPA (2003) required for the survival of tropical fishes and other aquatic animals. Higher pH value relatively was measured during the heavy rainy month (July) at all sites during the study period (p = 0.00) (Table 2), this could explained high concentration of carbonates and carbon dioxides, photosynthetic activity and low phytoplankton abundance (Ugbogu *et al.*, 2009, Embaye *et al.,* 2017) and low mean pH measurement was recorded at Simbo site (8.73±0.05) (p > 0.05) (Table 1). The pH of Lake Langano is ranged in the permissible limit (6.5-8.5) recommended by the WHO (2011) and Gray (2008) and falls as slightly alkaline lake.

Table 2. Temporal means concentration of heavy metals and physico-chemical parameters of Lake Langano

Parameters	Months							p values
	January	February	March	April	May	June	July	
NO_3^- (mg/l)	6.97±3.38[a]	6.37±2.05[a]	9.19±4.01[a]	16.8±1.06[a]	11.96±1.2[a]	65.21±1.93[b]	62.24±1.07[b]	0.00
PO_4^{3-} (mg/l)	0.9±0.16[a]	1.15±0.2[a]	0.22±0.13[b]	0.01±0.001[b]	0.08±0.002[b]	0.002±0.00[b]	0.001±0.00[b]	0.00
pH	8.86±0.23[a]	8.52±0.08[a]	8.29±0.08[a]	8.57±0.01[a]	8.56±0.03[a]	8.57±0.016[a]	10.37±0.25[b]	0.00
Conductivity (µS/cm)	1722.75±6.61[bc]	1787.5±4.19[c]	1740.5±8.31[bc]	1634.75±5.6[ab]	1635.75±3.2[ab]	1675±3.7[abc]	1586.5±9.1[a]	0.00
TDS	866.01±1.78[bcd]	893.5±2.9[d]	872.75±4.94[cd]	853±2.3[bcd]	819.5±9.95[ab]	834.25±1.93[bc]	783.5±9.12[a]	0.00
Water temperature (^{0}C)	30.5±0.61[b]	28.42±1.75[ab]	30.15±2.04[b]	25.38±0.41[ab]	26.32±0.46[ab]	24.6±0.53[a]	24.72±0.92[a]	0.003
Water transparency (m)	0.26±0.03[a]	0.25±0.02[a]	0.31±0.03[a]	0.25±0.02[a]	0.27±0.006[a]	0.22±0.018[a]	0.26±0.02[a]	0.23
Cu (mg/l)	0.27±0.16[a]	2.44±1.7[ab]	3.32±0.05[abc]	6.54±0.53[bc]	8.85±0.95[c]	1.3±0.01[ab]	0.003±0.001[a]	0.00
Zn (mg/l)	0.15±0.05[a]	0.39±0.2[a]	0.09±0.06[a]	6.88±4.05[a]	2.00±0.91[a]	2.81±0.43[a]	1.45±0.38[a]	0.14
Cd (mg/l)	0.73±0.17[a]	0.64±0.16[a]	4.67±0.86[ab]	15.82±3.7[ab]	16.85±1.63[b]	0.001±0.00[a]	0.003±0.002[a]	0.003

The concentration of TDS of the lake was increased during the none rainy months (January to April) of the study period ($p = 0.00$) (Table 2), this ascribed with high dissolved cations and anions, anthropogenic activities like washing and bathing, high temperature, frequent watering of livestock encourages organic matter by releasing manure and effluents from the catchment (Priyanka *et al.*, 2013; Joshi *et al.*, 2016). Lake Langano is highly saline, hard water and toxic to all aquatic life at all life stages with rapid phytoplankton growth and sewage contamination. All sites have been shown high concentration of TDS; beyond WHO (2011) maximum (500mg/l) allowable concentration that causes gastrointestinal irritation.

The concentration of NO_3^- showed very high variation throughout the study period and it ranges from 0.577 to 87.61mg/l temporally ($p = 0.00$) with high mean (29.44±32.74mg/l) at Simbo site and low (16.34±16.61mg/l) at Hara Langano site ($p = 0.07$) (Table 1). High concentration of NO_3^- was measured during the rainy months of the study period at all sites that explained by high use of agricultural fertilizers to boost crop yield, discharging of animals extracts (manure), introduction of decaying of animals and plants remains as result of heavy precipitation (Jadhav *et al.*, 2013). High and low mean (0.40±0.67mg/l and 0.25±0.30mg/l) ($p = 0.06$) concentration of PO_4^{3-} was observed at Simbo and Bushangari sites respectively (Table 1), whereas temporally high (1.15±0.2mg/l) and low (0.001±0.00 mg/l) ($p = 0.00$) mean concentration measured during the months of February and July respectively (Table 2). The concentration of PO_4^{3-} Lake Langano was high during the none rainy months of the study period, this associated with dilution level, high detergents from washing of clothes and excreta of aquatic animal, regeneration of phosphorus by zooplankton, hippopotamus and fish (Jadhav *et al.,* 2013). The concentration of NO_3^- of Lake Langano is above the allowable limit recommended by EPA (2003) (10mg/l) and WHO (2011) (50mg/l), however high concentration of NO_3^- is important in protein, DNA and ATP synthesis and growth of aquatic plants.

ZOOPLANKTON DIVERSITY AND ABUNDANCE

A total of 21 species of zooplankton belonging to Rotifera, Cladocerans and Copepode clade were identified in composite samples collected from lake (Table 2). Spatio-temporal species richness of zooplankton of Lake Langano is given Fig. 2. The species richness was high during dry (January to April) months of the study period. The number of cladocerans species was high at all sites during both seasons. The smallest Shannon Weaver diversity index recorded during March (Fig. 3).

*Table 3. Zooplankton species identified from Lake Langano (+ = presence, * = absence)*

Clade	Species	Sites			
		Bushangari	Hara Langano	Simbo	Sabana
Rotifera	*Hexarthra intermedia*	+	*	*	*
	Cephalodella gibba	*	+	*	*
	Polyarthra vulgaris	*	+	*	*
	Ascomorpha ecaudis	*	*	*	+
	Keratella lenzi	*	+	*	*
	Brachionus patulus	*	+	*	*
	Trichocerca similis	+	*	*	*
	Parabroteas sarsi	+	+	*	+
Cladocera	*Daphnia carinata*	+	+	*	*
	D. longiremis	*	+	*	*
	D. pulex	+	+	+	+
	D. parvula		*	+	*
	Moina micrura	+	+	+	+
	M. rostrata	+	*	*	*
	Eubosimina longispina	*	+	*	+
	Diaphanosoma birgei	*	+	*	+
Cyclopoida Copepoda	*Halicyclops neglectus*	*	*	+	*
	Megacyclops viridis	*	*	+	+
	Ectocyclops phaleratus	*	*	+	*
	Afrocyclops gibsoni	*	*		+
Calanoida Copepoda	*Naupliar stage*	+	+	+	+

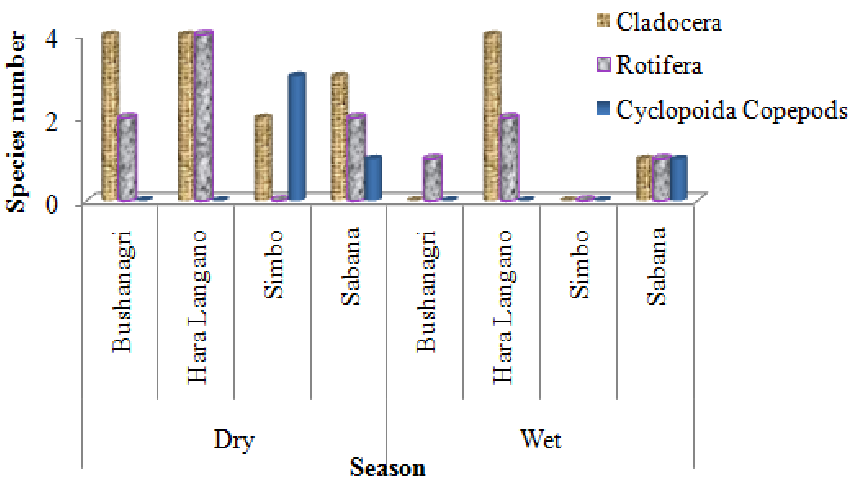

Fig. 2. Spatio-temporal pattern of species richness of zooplankton of Lake Langano

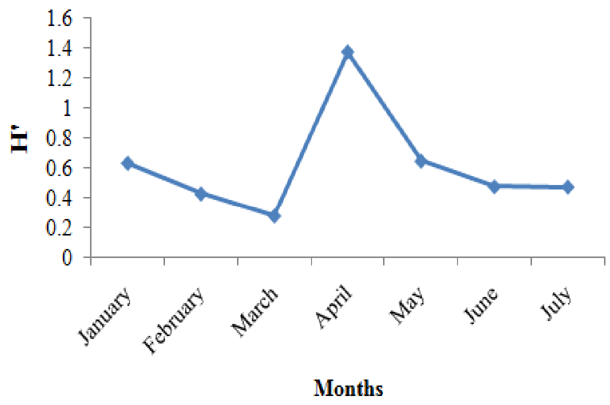

Fig. 3. Temporal Shannon-Weaver diversity index pattern of zooplankton of Lake Langano

Zooplanktons play a pivotal role in mediating the transfer of energy from lower to higher trophic levels and as ecological indicators of aquatic system. Low number of species was recorded at Simbo site throughout the study period that associated with high water temperature, NO_3^-, PO_4^{3-} TDS, Zsd, fish predation and Zn and low food availability due pelage of the site (Embaye *et al.,* 2017). The qualitative occurrence of *D. carinata, D. longiremis, D. parvula, D. pulex, E. longispina* and *D. birgei* were sparsely and rarely at all sites due high concentration of TDS, conductivity, water temperature and PO_4^{3-} and *M. micrura* and *M. rostrata* frequently occurred at Hara Langano, Simbo and Sabana sites, generally they had frequently occurred at Hara Langano site this relates to dispersal nature, low fish predation and NO_3^- and high food availability due inlet nature of the lake with high organic matter (Embaye *et al.,* 2017). Additionally, most cladocerans species are frequently occurred from September to November and early dry months of the year in tropical and subtropical lakes (Dagne, 2010). Few species of *Daphnia* were observed at Lake Langano this is an indication of the lake is polluted (Jappesen *et al.*, 2003; Dejenie, 2008; Paerveen *et al.,* 2010). Four species (*A. gibsoni, H. neglectus*, *E. phaleratus* and *M. viridis*) of Cyclopoid copepodes were only occurred at Simbo and Sabana sites during April and May this associated with habitat preference, high tolerance of to pollution and negatively correlated to water temperature, TDS, conductivity, Zsd and PO_4^{3-}. Most rotiferan species were observed at Hara Langano and Bushangari sites that ascribed to the inlet of the lake with high dilution and/or low concentration of physico-chemical variables and heavy metals (NO_3^-, PO_4^{3-}, Zsd, conductivity, TDS and Zn) (Hansson *et al.*, 2004; Dorak *et al.*, 2014). The *H. intermedia, P. vulgaris, C. gibba, A. ecaudis* were frequently observed during January and February at Bushangari and Hara Langano site and rare or sparsely occurred at the remaining study months and sites.

Temporal fluctuation in the abundance of zooplankton of the lake ranged from 1300 to 6300 individuals m^{-3}. The number of individual's m^{-3} was peak during the month of April (Fig. 4). High abundance of zooplankton individuals m^{-3} recorded during the none rainy months of the study period at all sites this relates to low imputes of solute, NO_3^-, Cu, Cd, Zn, optimum water temperature (25^{0}C) and pH (6.5-8.5) that supports high abundance of phytoplankton on which zooplankton feeding, some species of rotifera and cyclopoid copepods have low predation pressure and high tolerance to pollution (Dagne, 2010; Paerveen *et al.,* 2010; Sayeswara *et al.*, 2011; Embaye *et al.,* 2017). Low mean (3.85± 7.26 ind. m^{-3}) abundance of cladocerans was recorded at Bushangari site (Table 4). The spatio-temporal variation in the abundance of zooplankton of the lake was statistically significant (p = 0.031).

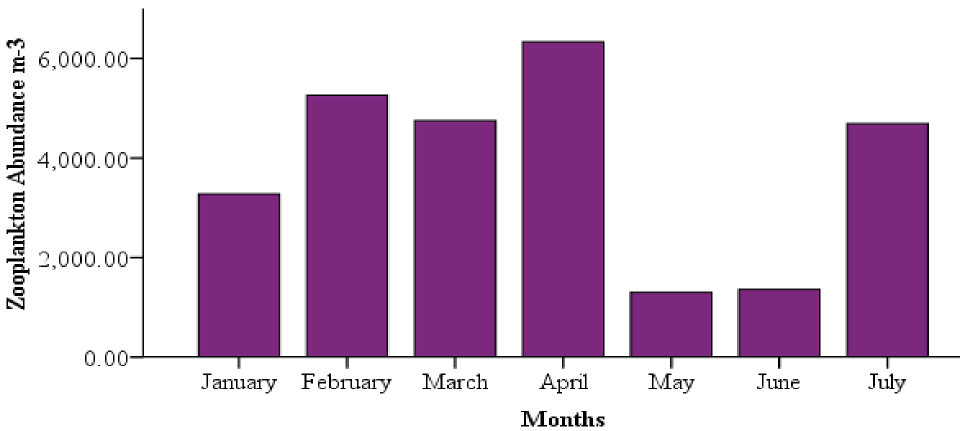

Fig. 4. Temporal fluctuation in density (ind. m^{-3}) of zooplankton of Lake Langano

Table 4. Spatial fluctuation of mean abundance of zooplankton of Lake Langano (ind. m^{-3})

Clade	Sites			
	Bushangari	Hara Langano	Simbo	Sabana
Cladocera	3.85±7.26	8.14±11.32	6.71±10.51	5.82±8.48
Cyclopoida copepods	0.00±0.00	0.00±0.00	4.71±12.47	1.89±6.65
Rotifera	1.00±1.82	3.14±4.70	0.00±0.00	1.21±2.75
Naupliar stage Calanoida	16.00±19.11	10.00±7.63	4.00±5.03	8.75±11.51

The CCA plot for the relationship between rotiferan and Naupliar stages of calanoid copepodes, cladocerans and cyclopoid copepods zooplankton and measured environmental variables are given in Figs 5, 6 and 7 respectively. 91.27% of the variation in abundance and composition of rotiferan and Naupliar stages of calanoid copepods of the lake was explained by NO_3^-, Zn, Cd, PO_4^{3-} Zsd, TDS, water temperature and conductivity. Maximum abundance rotiferan were reordered at Hara Langano site with few during June and July of the study period (Fig. 5). Rotiferan have high ability of living in disturbed habitat, high pollution and low pressures of predation by fish due to its small body size (Acuna *et al.*, 2007; Sayeswara *et al.*, 2011).

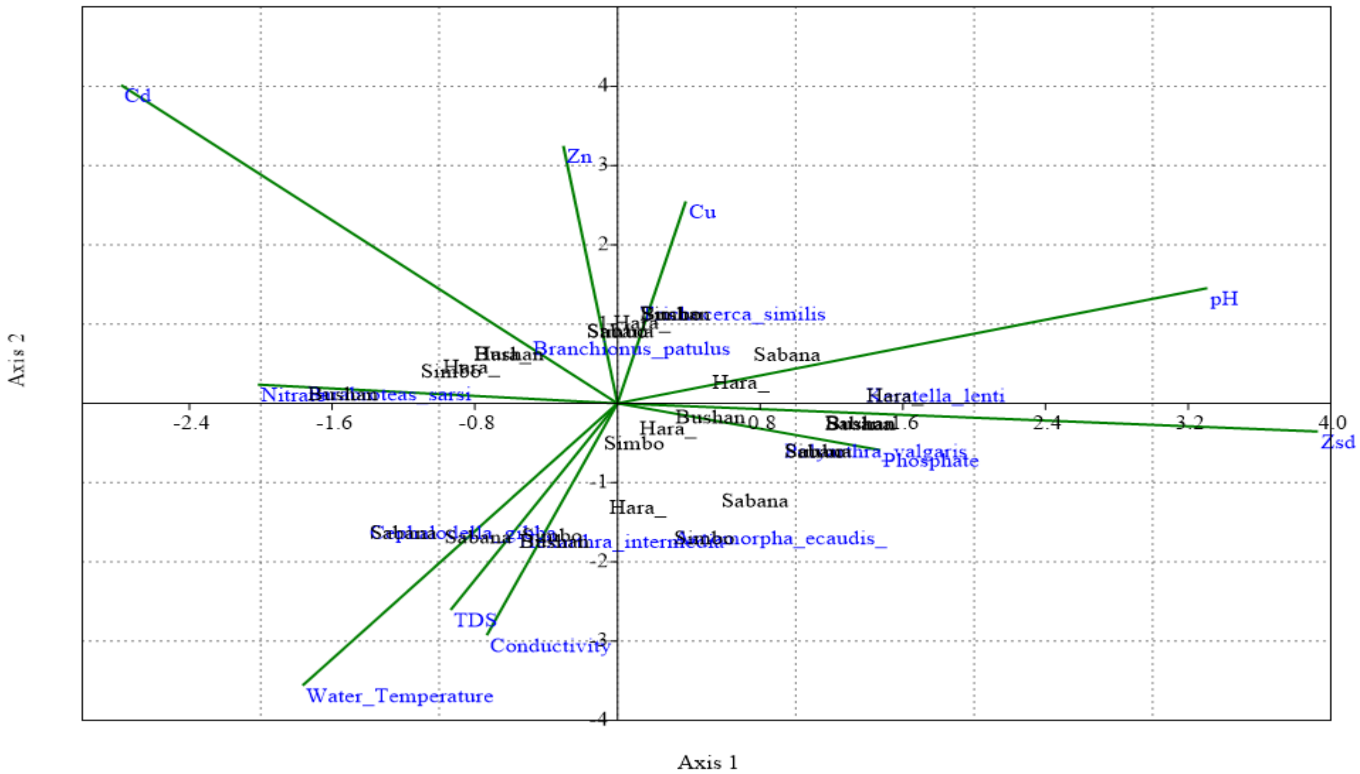

Fig. 5. CCA plot of the association between the environmental variables and rotiferan and Naupliar stage of calanoid copepods species of Lake Langano (Where, Bushan= Bushangari, Hara= Hara Langano)

The composition and abundance of cladocerans zooplankton of Lake Langano was determined highly (97.341%) by PO_4^{3-}, conductivity, Zsd, Cd, Cu, TDS, and water temperature variables of the lake. The relative and numerical abundance of cladocerans were high during the months of April and July associated with some littoral species becomes more abundant in lentic habitat when the volume of the aquatic body is high and food availability (Asmelash, 2009; Sayeswara *et al.*, 2011).

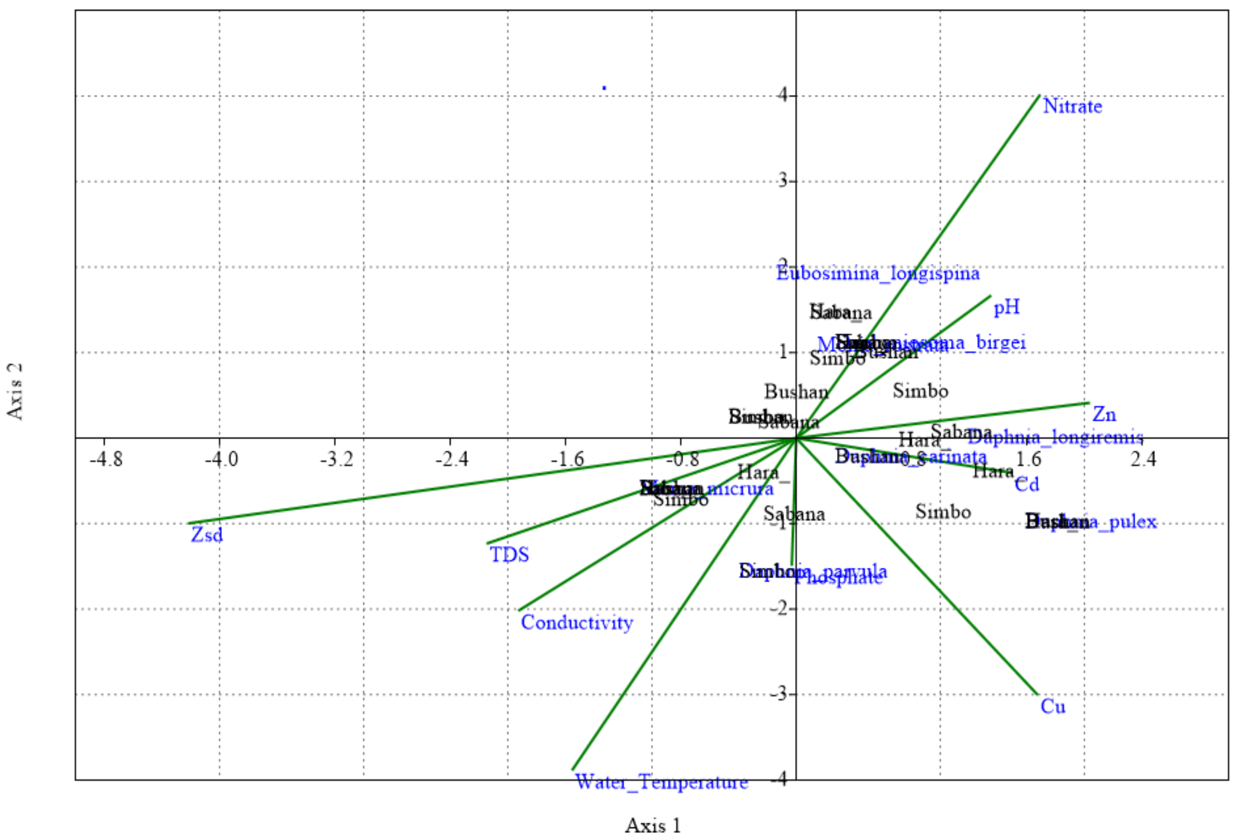

Fig. 6. ***CCA plot of the association between the environmental variables and cladocerans species of Lake Langano (Where, Bushan= Bushangari, Hara= Hara Langano)***

More than 93% the fluctuation in abundance and composition of cyclopoid copepods of the lake was explained by PO_4^{3-}, pH, water temperature and Zn. The abundance of cyclopoid copepodes were maxima at Simbo site with few species during the month of April and no cyclopoid recorded from Hara Langano and Bushangari sites that relates low Zsd and high inflow of water. The abundance of cyclopoid copepods negatively correlated with TDS, conductivity, Zsd, pH, PO_4^{3-} and water temperature of the lake (Fig. 7). The cyclopoid copepods have high level of tolerance to pollution.

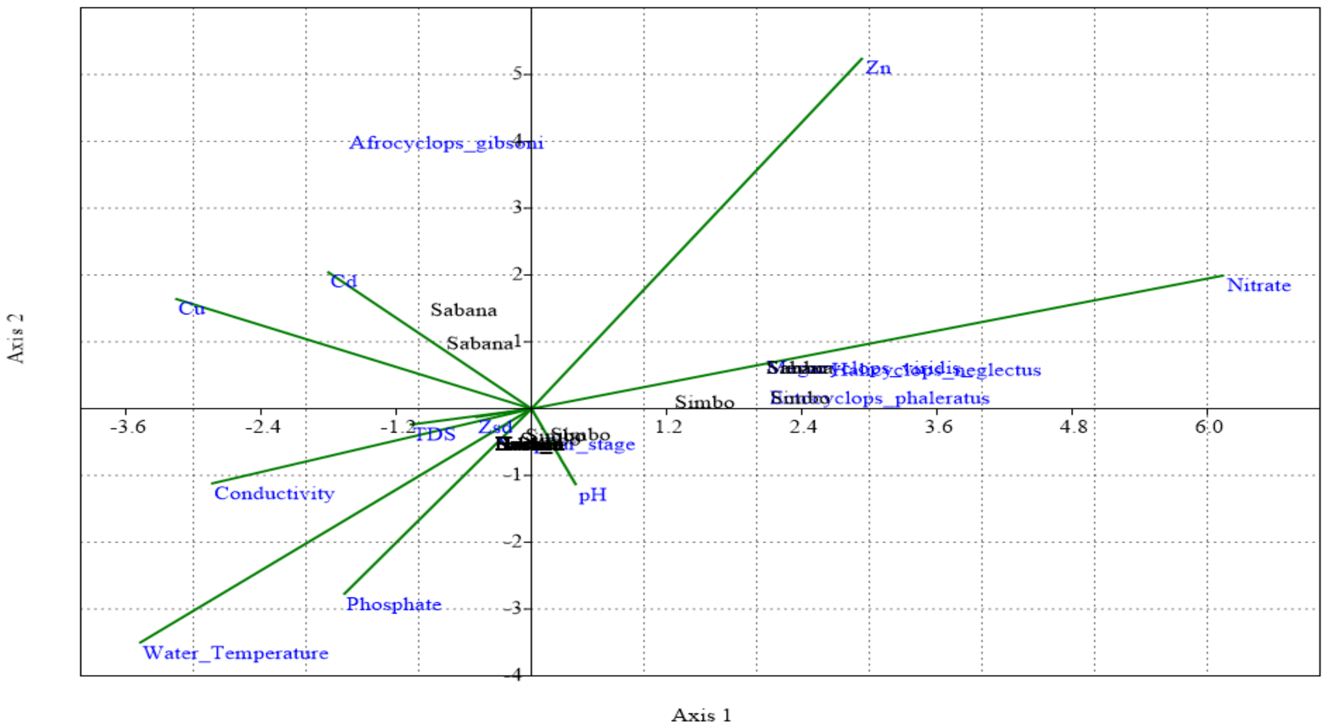

Fig. 7. CCA plot of the association between the environmental variables and cyclopoid copepodes species of Lake Langano

4 CONCLUSION

Most of the concentration of physico-chemical variables and heavy metals were beyond the limits suggested by WHO and EPA and varied both spatially and temporally. At all sites high concentration of water temperature, conductivity, Zsd, PO_4^{3-} and TDS were observed during the none rainy months, whereas Cd, Cu, Zn and NO_3^- high during the rainy months of the study period. Almost high concentration of heavy metals and physico-chemicals parameters measured at Hara Langano sites throughout the study period. Twenty one species of zooplankton species belongs to taxa of cladocerans, rotiferan, cyclopoida and Calanoida copepodes has been identified. The zooplankton exhibited spatiotemporal dynamics both in species diversity and abundance. High number of species recorded at Hara Langano site and during the none rainy months of the study period. The maximum abundance (indi.s m^{-3}) of cyclopoid copepodes and cladocerans observed at Simbo and Hara Langano sites respectively. The concentration of NO_3^-, Zn, Cd, PO_4^{3-} Zsd, TDS, water temperature and conductivity were found in the spatiotemporal variation (91.27%) of the abundance and composition of rotiferan and Naupliar stages of calanoid copepods, whereas 97.34% the dynamics of the composition and abundance of cladocerans determined by PO_4^{3-}, conductivity, Zsd, Cd, Cu, TDS, and water temperature variables of the lake.

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