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The impact of abiotic environmental factors on the occurrence, assemblages and diversity of freshwater zooplanktons in lake tanganyika, burundian littoral

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Abstract
The present study was conducted on Burundian coast of Lake Tanganyika in 4 sampling sites to identify and to estimate the spatial abundance of zooplankton community and to analyze whether physicochemical properties of water influence significantly the occurrence of zooplankton population. During the survey, it has been realized that zooplankton organisms were very few in number and taxonomic diversity and was comprising of 3 orders: Cyclopoida, Calanoida (Copepods) and Cladocera represented by Diaphanosoma. 12species belonging to 4families have been noted from all study sites. The relative diversity index of families revealed that the family Diaptomidae was dominant with 5species (41.7%) followed by family Cyclopidae with 4species (33.3%), then family Sididae with 2species (16.7%) while the Temoridae family was last with a single species (8.3%)
The results of species richness and the Cumulative abundance of the sampling sites showed that zooplankton species and density were variable among stations. 11species were identified at Rumonge site comprising 1152 individuals per liter followed by Kajaga and Mvugo sites with same specific richness of 10 species but with different cumulative abundance of 830 and 502 individuals per liter respectively and Nyamugari site was in last position with 8 species comprising 219 individuals per liter. Besides, the results of Canonical Correlation Analysis (CCorA) between the environmental parameters and zooplankton biomass have shown that the abundance and proliferation of some zooplankton species are affected by the physico-chemical parameters concentration by acting as either inhibitors or accelerators for zooplankton species growth.

Keywords: zooplankton, environment factors, lake tanganyika

1. Introduction
In recent years, coastal ecosystems are influenced by the highest degrees of Industrialization and anthropogenic activities which in turn influence the coastal productivity (Rakhesh *et al*. 2013) [41]. The zooplankton species composition in a water body is the result of the interactions between the abiotic and biotic factors. These factors determine the rate of metabolic transformations, the efficacy of immune systems and reaction patterns of bodies to stressors (Kinne, 1964; Roddie *et al*., 1984) [34, 44]. Zooplankton is one of the most important biotic elements that impact all functional aspects of aquatic ecosystems and often functions as important intermediate link in the pelagic food web, transfer of energy from producer to aquatic carnivores. The presence and distribution of plankton population is depending on multiple factors like climate change, physicochemical characteristics and biotic factors (Alexander, 2012; Cottenie *et al*., 2001; Ahmad *et al*., 2011; Rajagopal *et al*., 2010; Richardson, 2008) [2, 16, 1, 40, 43]. Zooplankton communities are highly subject to physical processes in the water column, and thus constitute the perfect biological indicators of climate change (Fromentin and Planque, 1996; Beaugrand *et al*., 2002; 2003; Fernandez de Puelles *et al*., 2004) [24, 10, 9, 23]. The variations in the abundance and structure of zooplanktons community are very sensitive to environmental changes (Harris *et al*., 2000) [31] as these organisms respond quickly to a wide range of environmental changes such as water temperature, pH, Conductivity and nutrients (Yakubu *et al*., 2000) [52] and the distribution and abundance of these organisms in water bodies can provide an useful information on the level of water pollution and health of the environment where they are found (Gajbhiye and Desai, 1981) [26]. Besides its importance in the food chain and its sensitivity to climate change, zooplankton is used to assess the impact of global change (Drira, 2009) [20] and differing varieties of species, biomass diversity and wealth of zooplankton groups can be used to determine the strength of a biological system. In freshwater communities, along with fish, they are the main food supplement to many other marine species (Walsh, 1978) [51]. The potential of zooplankton as a bioindicator species is high on the grounds that their development and conveyance are subject to some abiotic (e.g. temperature, saltiness, stratification, and pollutants) and biotic parameters (e.g. limitation of food, predation and competition) (Ramchandra *et al*. 2006) [42]. Many researches are devoted to find out how changes in the various environmental factors affect the zooplankton and what changes can be expected as a result. In recent days, extensive research work has been undertaken in the field of plankton, specifying as an indicator species of certain environment and adopting this technique for scientific fishing. The description of zooplankton species of Lake Tanganyika have been made by Sars (1909) [47], Gurney (1927) [29] and Lindberg (1951)

[36] on Copepoda, Harding (1957) [30] on Cladocera, and Rousselet (1910) [46], Beauchamp (1932) [8] and Gillard (1957) [27] on Rotifera. The absence or scarcity of cladocerans and rotirers in the open water and the richness of endemic cyclopoids have been noticed to be the characteristics of zooplankton in Lake Tanganyika (Cunnington,1920; Lindberg, 1951) [18, 36] and despite this unique character of composition, only a few studies have been made from an ecological viewpoint. In this context, the present study was devoted to identify the most common freshwater zooplankton occurring presently in Lake Tanganyika and to determine whether physicochemical properties significantly impacted zooplankton occurrence, hence, the present study was aimed to investigate the state of interrelationship between zooplankton assemblages and environmental characteristics in Lake Tanganyika. Furthermore, the knowledge about the distribution, abundance and production of zooplanktons of the lake are essential for understanding the lake ecosystem.

2. Materials and Methods

2.1 Study area

The water sample for laboratory analyses was carried out at 4 sampling sites (Kajaga, Nyamugari, Rumonge and Mvugo) belonging to the Burundian coast. The Table1 and Figure1 show the geographical location of the study areas:

Table 1: Geographical location of the study sites

Study sites	Geographical Location				
	Province	Commune	Longitude-East	Latitude-South	Altitude
Kajaga	Bujumbura Rural	Buterere	029° 17’ 56’’	03° 20’ 55’’	783 m
Nyamugari	Bujumbura Rural	Kabezi	029° 20’ 24’’	03° 30’ 27’’	776 m
Rumonge	Rumonge	Rumonge	029° 26’ 03’’	03° 58’ 23’’	767 m
Mvugo	Makamba	Nyanza-Lac	029° 34’ 06’’	04° 17’ 42’’	810 m

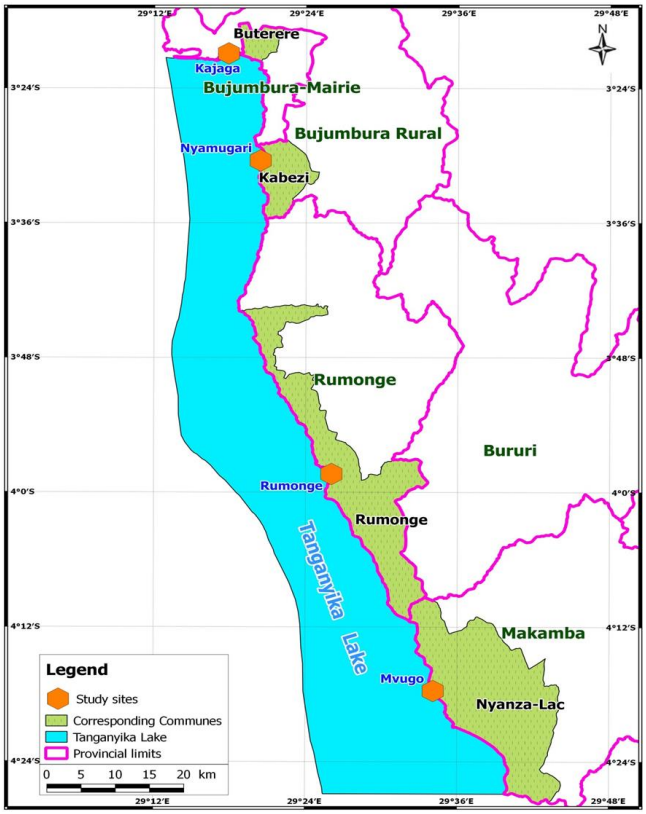


Fig 1: Map of the study area showing sampling sites

2.2 Collection of water samples for physico-chemical analysis

The field data collection has lasted 3months (January, February and March, 2018). The water sample for Physical and chemical analyzes was collected in the morning time using plastic containers. Temperature, Electrical conductivity, pH and dissolved oxygen have been measured in-situ using electrometric method (conductivity meter and pH-meter) while the remaining parameters were determined in Laboratory using the standard methods (APHA, 2005; Trivedy and Goel, 1986) [4, 50]. The methods adopted for water quality analysis and the used instruments are listed in the Table2:

Table 2: Analytical methods adopted to determine quality of lake water

Parameters	Methods	Equipments
Turbidity (NTU)	Turbidity tube method	Turbiditimeter, Turbidity tube or Nephelometer
Temperature	Temperature sensitive probe	Mercury thermometer
Total Dissolved Solids	Evaporation method, Electrometric, and Gravimetric method	Conductivity meter
Transparency	Secchi Disk Visibility Method	Secchi disk
pH, Electrical Conductivity	Electrometric Method	pH-meter, Conductivity meter
Dissolved Oxygen	Alsterberg Azide Modification of the Winkler's Method.	Dissolved Oxygen meter
Total hardness, Calcium and Magnesium	EDTA Titration Method	-
Chlorides	Titration by $AgNO_3$, Mohr's method.	-
BOD	5 days incubation at 20^0C followed by titration	BOD Incubator
Total alkalinity	Titration by H_2SO_4	-
COD	Digestion followed by titration	COD Digestor
Total Carbon, Total Nitrogen	Titrimetric method	-
Total. Phosphorous	Digestion and ascorbic acid Spectrophotometric Method	Spectrophotometer
Iron, Lead, Cadmium, Chromium, Copper, Selenium, Arsenic.	Atomic Absorption Spectrophotometric Method	Spectrophotometer

2.3 Sampling and taxonomic identification of zooplankton species

Water sample was collected from the surface in the morning time. 100 liters of the collected water were filtered through a cloth net of mesh size 63 µm and diameter 16cm (Figure 2A). The final volume of the filtered sample was 125ml and was preserved by adding 5ml of 4% formalin solution and kept for 24 hours undisturbed to allow the sedimentation of zooplankton suspended in the water. After 24 hours, the supernatant was removed carefully using pipette and the final volume of concentrated sample ready for analysis was 50ml. For both qualitative and quantitative analysis, a concentrated subsample of 1ml was transferred in the cavity of Sedgwick-Rafter cell (Figure 2C: a slide with a rectangular cavity of dimensions 50mm*20mm*1mm or $1000mm^3$=1ml) using a pipette and was covered by a cover glass of an appropriate and known area to estimate the numbers of individuals by observation under light microscope compounds (Figure2B). Zooplanktons were identified up to a taxonomic precision of species level, family and order in both Cladocera and Copepoda using identification keys as per Ramachandra *et al*. (2006) [42]. The species belonging to each group were recorded, the number of individuals in each species was counted and the number of organisms was expressed in total organisms per liter using the following formula:

Zooplanktons **(**Total organisms per Liter**)** $= \frac{N \times C}{V}$,

With N: Organisms per Liter $= \frac{R \times 1000\ mm^3 \times 10^3}{L \times D \times W \times S}$

Where: **N =** Number of zooplanktons counted in 1ml of concentrated sample but expressed per liter.

C = Total volume in ml of the concentrated sample (50ml, after removal of the supernatant).

V = Total volume in ml of original sample (100 000ml, before filtration with plankton net).

R = Total number of organisms counted per subsample (in 1ml)

L = length of each strip (mm)

D = depth of a strip (mm)

W = width of a strip (mm). It is corresponding to the diameter of the view field and is measured with a transparent graduated ruler or 1cm² of graph paper instead of the slide.

S = number of strips counted.

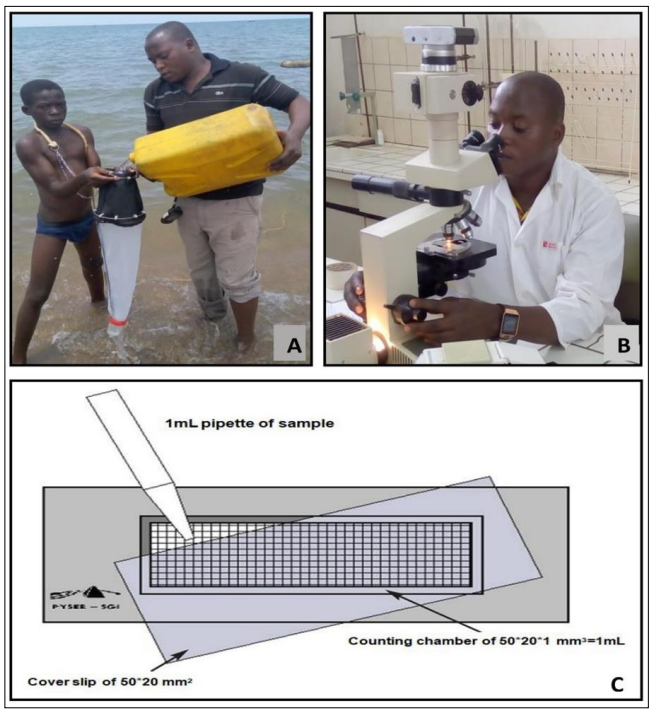


Fig 2: Planktons collection by filtering through a cloth net (A); Observation of Plankton cells under light microscope (B) and Sedgwick-Rafter counting cell (C).

Species biodiversity measurement

Specific richness (S), Shannon Wiener Index (1949) [48] and Pielou's evenness index (1966) [39] have been used for measuring species diversity. Indeed:

1. The Specific richness (S) is the simplest measure of biodiversity and provides simply the total number of species recorded on a site. Margalef's diversity index is widely used is given by the following equation: (D_{ma}) = (S-1) / ln N.

Where: **N** = the total number of individuals in the sample, **S** = the total number of species recorded.

2. Shannon-Weaver Index (1949) represents the average information provided by a sample on the stand structure from which the sample originates and how individuals are distributed among different species (Daget, 1976)

[19]. It is the most commonly used index in ecology (Frontier, 1983; Gray *et al*., 1979; Collignon, 1991; Barbault, 1992) [25, 28, 15, 7] as it considers both abundance and species richness. It is calculated as follows: Shannon Weiner Index (H') = $-\sum_{i=1}^{S}[ni/N * \log_2(ni/N)]$

Where**: S**= Total number of species in the sample
ni = Number of individuals of a species in the sample
N= Total number of individuals of all species in the sample. It varies from 0 to infinity. The higher the value of the index H', the greater the diversity. H' is minimal (= 0) if all individuals in the population belong to a single and same species. This index is maximal when all individuals are equally distributed over all species (Frontier, 1983; Hily, 2003) [25, 32].

3. Pielou's evenness index (E) (1966) also called equidistribution index (Blondel, 1979) [12] measures the equitability or equidistribution of the species in the station in comparison with an equal theoretical distribution for all the species. Evenness is calculated according to the following formula: $E = H'/ H'_{max} = H'/ \log_2 S$.

Where: H'= Shannon-Wearver Index,
$H'_{max} = \log_2 S$,
S = Total number of species present
log2: the logarithm in base 2
The evenness index (E) varies from 0 (single species dominance) to 1 (equidistribution of individuals in the samples. It is maximal when the species have identical abundances in the population, and it is minimal when a single species dominates the whole population.

Statistical Analysis
Statistical analysis was performed using: SPSS 20 and XLSTAT 2019 and this analysis comprises of Multivariate analyzes including Correspondence Factor Analysis (CFA) and Canonical Correlation Analysis (CCorA) which summarize the data correlation structure described by several quantitative variables by identifying underlying factors common to the variables for explaining a significant portion of the data variability.

Results
Physico-chemical characteristics of water
In the present investigation, the physical and chemical parameters evaluated were Turbidity (Tur),Temperature (Te), Potential of Hydrogen (pH), Transparency (Tr),Total Alkalinity (TA), Electrical Conductivity (EC),Total Dissolved Solids (TDS),Chlorides (Cl^-), Total Hardness (TH), Calcium (Ca2+), Magnesium(Mg2+), Iron (Fe), Total Carbon (TC), Total Nitrogen(TN), Total Phosphorus(TP), Dissolved Oxygen(DO), % of Oxygen Saturation, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and some heavy metals like Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Selenium (Se) and Arsenic (As).The spatial variation of the analysis results are presented in table3.

Table 3: Spatial variation of Physico-chemical characteristics of water.

Parameters	Kajaga	Nyamugari	Rumonge	Mvugo
Tur (NTU)	0.5	9.8	1.5	0.65
Te (°C)	27.1	28	29.8	29.4
Tr (cm)	210	130	175	180
pH	8.85	8.88	8.82	8.5
TA (mg. L^{-1})	300.5	340.6	335.6	355.6
EC (µS/cm)	662	664	658	661
TDS (mg. L^{-1})	443.54	444.88	440.86	442.87
Cl^-(mg. L^{-1})	47	30.8	39.25	35.15
TH (mg. $CaCO_3$. L^{-1})	210.4	189.2	211.3	172.9
Ca^{2+} (mg. L^{-1})	54.65	34.95	43.18	39.22
Mg^{2+} (mg. L^{-1})	17.93	24.74	25.11	18.19
Fe (mg. L^{-1})	0.021	0.018	0.161	0.089
TC (mg. L^{-1})	80.4	78.92	71.32	79.45
TN (mg. L^{-1})	0.379	0.1502	0.1079	0.1908
TP (mg. L^{-1})	1.572	1.671	0.786	0.685
DO (mg. L^{-1})	7.514	7.393	7.162	7.212
DO (%)	94.5	94.66	94.99	94.03
COD (mg. L^{-1})	75	30	25	25
BOD (mg. L^{-1})	15	10.6	8	7.5
Cd (ppm)	0.002	0	0	0
Cr (ppm)	0.031	0.04	0.002	0
Cu (ppm)	0.162	0.081	0.079	0.008
Pb (ppm)	0.083	0.062	0.079	0.034
Se (ppm)	0.006	0.002	0	0
As (ppm)	0	0	0	0

3.2 Zooplanktons analysis
During the survey, it has been realized that zooplankton organisms of the lake were very few in number and taxonomic diversity and was consisted of 3 orders: Cyclopoida, Calanoida (Copepods) and Cladocera represented by Diaphanosoma. Indeed, 12species belonging to 4families have been recorded from all study sites. The relative diversity index of families (Figure 3) revealed that the Diaptomidae family was dominant with 5species (41.7%). The Cyclopidae family was in second position with 4species (33.3%), the Sididae family occupied the third position with 2species (16.7%) while the Temoridae family was last with a single species (8.3%). The results regarding quantitative analysis (Figure 3) showed that Rumonge site was ranked first with respective specific richness (S) and the Cumulative abundance of 11species and 1152individuals per liter, Kajaga and Mvugo site were equal to 10species as same specific richness(S) but with different cumulative abundance of 830 and 502 individuals per liter respectively. This places therefore Kajaga site in second position while Mvugo site was in third position. Nyamugari site was in last position with 8 as specific richness (S) comprising 219 individuals per liter. The table4 shows the qualitative and quantitative results of zooplanktons population while the relative diversity index of families as well as the results of specific richness and Cumulative abundance are shown on the figure3 respectively.

Table 4: Qualitative and quantitative results of zooplanktons population

Order → ***Family*** → ***Species***	**Acronyms**	**Kajaga (NO.L^{-1})**	**Nyamugari (NO.L^{-1})**	**Rumonge (NO.L^{-1})**	**Mvugo (NO.L^{-1})**
I. Order Cyclopoida I.1. Family Cyclopidae					
1. *Cyclops nanus*	CN	26	0	30	7

2. *Cyclops cunningtoni*	CC	23	3	31	13
3. *Cyclops attenuatus*	CA	19	8	27	11
4. *Cyclops simplex*					
4.1. *Cyclops simplex* copepodite	CSC	71	21	101	45
4.2. *Cyclops simplex* female	CSF	58	11	79	34
4.3. *Cyclops simplex* male	CSM	49	13	70	30
4.4. *Cyclops simplex* nauplii	CSN	75	17	110	48
II. Order Calanoida, II.1. Family Diaptomidae					
5. *Diaptomus africanus*	DA	37	12	0	15
6. *Diaptomus falcifer*	DF	46	9	63	26
7. *Tropodiaptomus cunningtoni*	TC	29	9	52	23
8. *Tropodiaptomus burundensis*	TB	43	7	65	28
9. *Tropodiaptomus simplex*					
9.1. *Tropodiaptomus simplex copepodite*	TSC	67	21	93	41
9.2. *Tropodiaptomus simplex female*	TSF	54	17	76	33
9.3. *Tropodiaptomus simplex male*	TSM	49	10	70	31
9.4. *Tropodiaptomus simplex nauplii*	TSN	116	33	171	75
9.5. *Tropodiaptomus simplex ovigerous*	TSO	59	28	87	39
II.2. Family Temoridae					
10. *Eurytemora sp.*	ES	9	0	12	0
III. Order Cladocera III.1. Family Sididae					
11. *Diaphanosoma birgei*	DBi	0	0	6	0
12. *Diaphanosoma brachyurum*	DB	0	0	9	3
Total of Species		10	8	11	10
Total of Individuals per Liter		830	219	1152	502

Where NI. L^{-1}: Number of Individuals per Liter

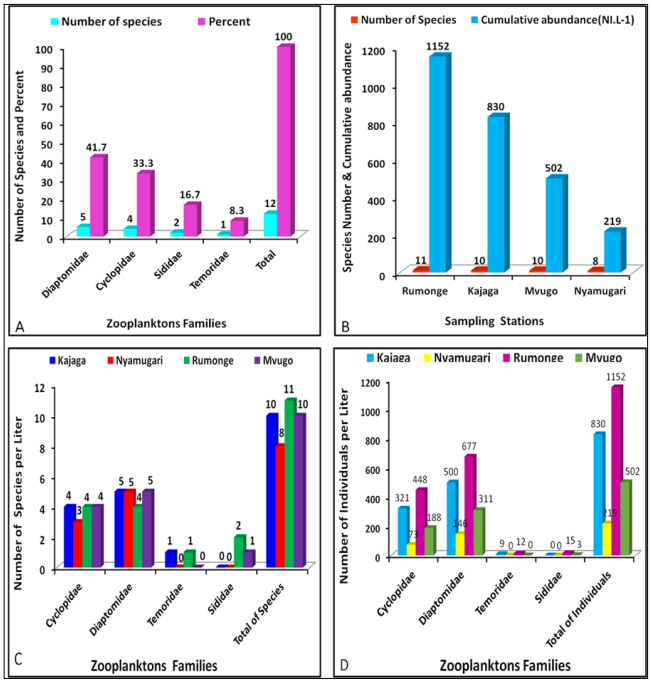


Fig 3: Relative diversity index of zooplankton families (A), species richness & Cumulative abundance of zooplankton individuals (B), density of zooplankton species (C) and individuals (D) per station and family.

3.3 Correspondence Factor Analysis

Correspondence Factor Analysis (CFA) explores linkages, similarities and dissimilarities between individuals based on their distances on the factorial planes. CFA therefore studies the association between two qualitative variables as well as

The proximities between the modalities of these variables. Zooplanktons species located on the right side of the F1 axis prefer mostly Kajaga, Nyamugari and mvugo sites which are propicous to their growth. This is the case for species belonging to the family diaptomidae (Figure 4B) such as TSO, CA, TSC, CSC, TSF, CSM and DA (Figure 4A). On the left side of F1 axis, the species belonging to the family cyclopidae, sididae and temoridae (Figure 4B) like DBi, DB, TSN, CC, CFS TB, TSM, DF, CN and ES are most abundant at Rumonge site (Figure 4A).

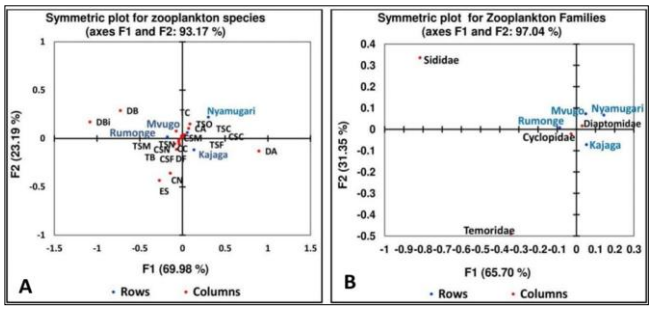


Fig 4: CFA plot showing linkages between the sampling sites and zooplanktons species (A) & the Sampling sites and zooplanktons families (B).

3.4 Effect of abiotic environmental characteristics of water on the abundance of zooplanktons community.

Physico-chemical parameters play a major role in determining the assemblages, diversity and occurrence of zooplankton population in a water body. The figure 5 show the relationship between the environmental factors (Physico-chemical variables) and zooplanktons population.

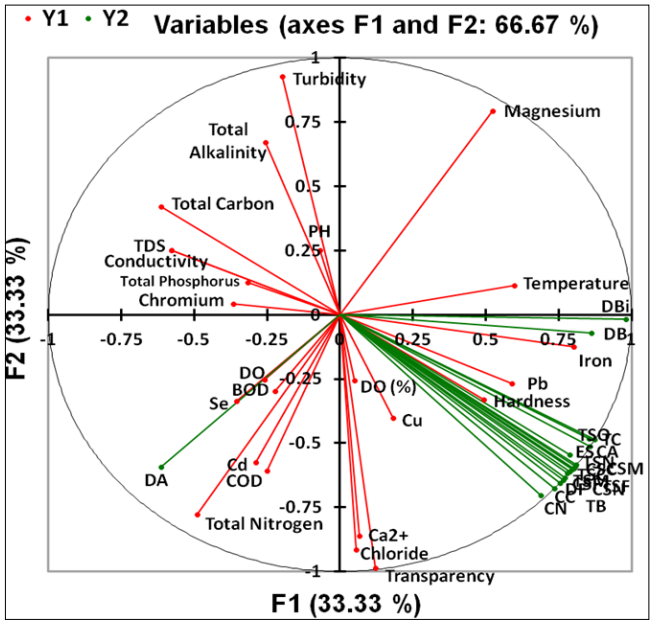


Fig 5: Canonical Correlation Analysis (CCorA) biplot showing relationship between the environmental parameters and zooplankton composition at sampling sites.

The Canonical Correlation Analysis (CCorA), shows that apart from *Diaptomus africanus*(DA) which is positively affected by Selenium, Dissolved Oxygen, BOD,Cadmium, COD, Total Nitrogen, Chromium, Total Phosphorus,TDS, Conductivity and Total Carbon, all zooplankton species recorded during the present investigation are positively correlated to Hardness, Lead, Iron, Temperature, Copper, DO saturation(%), Calcium, Chloride, Transparency and Magnesium and negatively correlated to Turbidity,Total Alkalinity, pH, Total Carbon, TDS, Electrical Conductivity, Total Phosphorus, Chromium, Selenium, Dissolved Oxygen, BOD, Total Nitrogen, COD and Cadmium. In general, it is realized that all zooplankton species recorded in the present study (except *Diaptomus africanus*) are located in the fourth quadrant of the trigonometric circle. The physico-chemical parameters of the first and fourth quadrant affect positively zooplankton species by accelerating their growth while those belonging the second and the third quadrant act as inhibitors for zooplankton species growth.

3.5 Zooplanktons species diversity analysis

Zooplanktons species diversity between the sampling stations using diversity indices are given in the table 5.

Table 5: Zooplanktons species diversity indices

Diversity indices	Sampling Stations			
	Kajaga	Nyamugari	Rumonge	Mvugo
1. Shannon Weiner Index (H') = $\sum_{i=1}^{S}[ni/N * \log_2(ni/N)]$	2.366	2.042	2.280	2.243
2. Pielou's evenness (E) = = H' / $\log_2 S$	0.712	0.681	0.659	0.675
3. Margalef index (D_{ma}) =(S-1) / ln N	1.447	1.299	1.419	1.339

Usually, Shannon Weiner Index varies from 0 to infinity and decreases with the decrease in diversity. In the present study, this index is very low with a variation of 2.042 to 2.366 and all the obtained values are close to 2 in all sampling stations.

Pielou's evenness reflects the species equidistribution in the population and varies from 0 to 1. It has1 value when the species have identical abundances in the population and it is 0 when a single species dominates the whole population. For the current investigation, the Eveness Index varies from 0.659 to 0.712 which are the values close to the average. This event shows that there are some species in the population tending to dominate others and moreover, the distribution of species in the population is not fair.

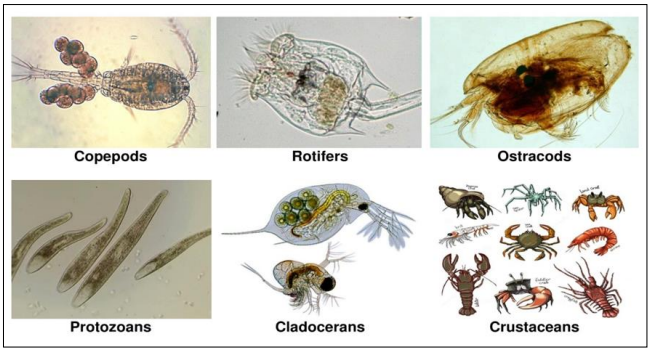
Margalef's diversity index was ranging from 1.299 to 1.447 by direct counting. Apart from Nyamugari station where Margalef's diversity index was low, the other 3 stations have indices a little bit high and are close to each other, which show that the environmental conditions favourable to the development of zooplanktons are almost the same.

Discussion

The word zooplankton is derived from the Greek *ζῴον* (zoon) meaning "animal", and *πλαγκτός*. (planktos) meaning wanderer (Thurman H.V.,1997)[49]. The freshwater zooplanktons comprise mainly of six groups (figure 6) such as Protozoa, Rotifers**,** Crustaceans**,** Cladocerans, Copepods and Ostracods (Ramachandra *et al*., 2006) [42] and fish eggs, larvae of larger animals such as annelids and fish. Zooplanktons constitute an important link in food chain as grazers (primary and secondary consumers) and serve as food for fish directly or indirectly. Therefore any adverse effect to them will be indicated in the wealth of the fish populations and monitoring them as biological indicators of pollution could act as a forewarning for fisheries especially when the food chain is affected by pollution (Mahajan, 1981) [37]. In fact, the use of zooplankton for ecological biomonitoring of the water bodies helps in the analysis of water quality trends, development of cause-effect relationships between water quality and environmental health and judgement of the adequacy of water quality for various uses. Zooplanktons population of Lake Tanganyika was composed of 3 orders such as: Cyclopoida, Calanoida (Copepods) and Cladocera represented by the Diaphanosoma.

Apart from the shortage of Jellyfish during the present study, the results obtained were in accordance with those found by Coulter (1991) [17] and Bwebwa (1996) [13] who found that the northern pelagic zooplanktons community of Lake Tanganyika is dominated by the crustacean copepods consisting mainly of *Tropodiaptomus simplex* and cyclopoid while the minor constituents in the pelagic environment are the jellyfish represented by *Limnocnida tanganyicae* and some scarce rotifers. In the present investigation, jellyfish and rotifers have not been identified due to the use of the large mesh size net (63 µm) which lets a large amount of rotifers pass through the net, since this group consists of smaller individuals. On the other hand, this could be explained by a low sampling frequency which decreases the possibilities of capturing the jellyfish, which is a scarce species of Lake Tanganyika, but also by the possible daily migrations that have been reported in several zooplankton groups (Dussart, 1989; Bwebwa, 1996; Isumbisho *et al*., 2006) [21,13,33]. The presence of *Diaphanosoma* (Cladocerans) at only Rumonge and Mvugo sites can be explained by the fact that there are no cladocerans in the lake itself, probably because of the high predation. The Cladoceran species found in the Lake Tanganyika basin were all found in the near-shore area and adjacent waters of

the lake. No species was found in pelagic habitat (Patterson and Makin, 1998) [38]. The Diaphanosoma identified from these two sites would likely come from coastal lagoons. On the other hand, the presence of Copepoda in almost all sampling sites may be a function of several characteristics related to the organisms themselves. The first is their ability to accept highly variable environmental conditions (Amoros and Chessel, 1985) [3]. The second is their resistance to more or less rapid fluctuations in the physical, chemical and biological characteristics of the environment (Dussart, 1989; Arfi *et al*., 1981, 1987) [21,5,6]. Finally, the possibility of surviving at the state of resting stages allows some species in this group to be transported from one habitat to another and thus to have a wider range (Amoros and Chessel, 1985; Khalki *et al*., 2004) [3,34]. Certainly, the variability observed in the distribution of zooplankton is due to abiotic parameters (e.g Climatic or hydrological parameters such as salinity, temperature, advection and stratification), to biotic parameters (e.g.limitation of food, competition, predation) or to a combination of both (Beyst *et al*., 2001, Christou, 1998, Escribano and Hidalgo, 2000 and Roff *et al*., 1988) [11,14,22,45]. Even if zooplanktons are present in a wide range of environmental conditions, many species are still limited by dissolved oxygen, temperature, salinity and other physicochemical factors.



***Source*:** Compilation by the author

Fig 6: Major groups of fleshwater zooplanktons.

Conclusion

The present study was intending to assess the effect of environmental factors on the abundance and diversity of zooplankton community. Zooplankton organisms of Lake Tanganyika were found very few in number and in taxonomic diversity and were comprising of 12species belonging to 4families: Diaptomidae, Cyclopidae, Sididae and Temoridae and to 3orders: Cyclopoida, Calanoida (Copepods) and Cladocera represented by Diaphanosoma. The results regarding quantitative analysis showed that Rumonge site was ranked first with respective species richness and the Cumulative abundance of 11species and 1152individuals per liter, Kajaga and Mvugo site were found to have same species richness (10species) but with different cumulative abundance of 830 and 502 individuals per liter respectively. This places therefore Kajaga site in second position while Mvugo site was in third position. Nyamugari site was in last position with 8 as species richness comprising 219 individuals per liter.The Canonical Correlation Analysis (CCorA), shows that apart from *Diaptomus africanus* which is positively affected by Selenium, Dissolved Oxygen, BOD,Cadmium, COD,Total Nitrogen, Chromium,Total Phosphorus,TDS, Conductivity and Total Carbon, all zooplankton species recorded during the present investigation are positively correlated to Hardness, Lead, Iron, Temperature, Copper, DO saturation(%), Calcium, Chloride, Transparency and Magnesium and negatively correlated to Turbidity,Total Alkalinity, pH, Total Carbon, TDS, Electrical Conductivity, Total Phosphorus, Chromium, Selenium, Dissolved Oxygen, BOD, Total Nitrogen, COD and Cadmium. In general, it is realized that all zooplankton species recorded in the present study (except *Diaptomus africanus*) are located in the fourth quadrant of the trigonometric circle. The physico-chemical parameters of the first and fourth quadrant affect positively zooplankton species by accelerating their growth while those belonging the second and the third quadrant act as inhibitors for zooplankton species growth.

Disclosure statement

No potential conflict of interest was reported by the authors with respect to the research, authorship and publication of this article.

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