Research Article
***Cameroon Journal of Biological and Biochemical Sciences* 2021, Vol 29, Serie 2, 31-47**
ISSN 1011-6451/*CJBBS*.2021. Published Online (March 2021) (www.camjournal-s.com)

DIVERSITY OF INFUSORIAN COMMUNITY STRUCTURE IN AN EQUATORIAL HYDRO SYSTEM: INFLUENCE OF ENVIRONMENTAL FACTORS

Ajeagah Gideon Aghaindum[1] , Acha Yanick ACHA[2]

[1, 2] Hydrobiology and Environment Laboratory, Faculty of Science, University of Yaounde 1, PO Box 812, Yaoundé, Cameroon.
Correspondence: [1]ajeagahg@yahoo.com, [2]yannickachaacha@gmail.com

Abstract

A study was carried out from December 2017 to July 2018 at 4 sampling stations in the Mingoa drainage basin in Yaounde, Cameroon on a monthly sampling frequency, inorder to assess the community structure of ciliated protozoans. Physico-chemical analysis revealed that the waters of the Mingoa river basin, were slightly basic (from 7.64CU ± 0.52CU to 7.83CU ±0.32CU), averagely oxygenated (from 20.25% ±10.53% to 69.25% ± 38.11%). The ciliate community of the aquatic ecosystems was averagely diversified and evenly distributed. Ciliates sampled belong to 3 classes, 10 orders, 22 families, 27 genera and 34 species. The density of individuals was relatively high for some species and significant correlations were seen between these protozoans and water physico-chemical parameters such as dissolved oxygen, and organic matter

Key words: ciliated protozoa, physico-chemical parameter, organic pollution and dynamism.

I Introduction

The hydrosphere is characterized by the presence of water which serves not only as a living environment for a very large number of aquatic organisms but also as an essential component of all living cells (Debashree, 2017). Water is thus an indispensible element for all forms of life on earth. To man, water is first of all necessary for metabolism but it is also very important for human activities such as agriculture and industry (Neveu *et al.*, 2001). In aquatic environments living organisms are in constant contact with the water that surrounds them. Consequently, any change in water quality resulting from a perturbation of the aquatic environment will affect the living organisms which live in and depend on it. The specific composition of the communities of these living organisms therefore depends on the quality of where they are found. Given the close relationship that exists between living organisms and water, aquatic organisms can thus be used to determine the state of health of a water body (Zébazé Togouet *et al.*, 2005).

It is in this light that many different groups of living organisms (bacteria, phytoplankton, zooplankton and benthic macro invertebrates), called bio-indicators have being used in recent times in the evaluation of water quality (Barbour *et al.*, 1991). These organisms respond to changes in the aquatic environment. Changes in the community specific composition of these organisms constitutes a base for the evaluation of the biological effects of pollution (Cairns *et al.*, 1972). Ciliates which constitute part of micro zooplankton and other protozoans are able to respond faster to the presence of a contaminant than metazoans of the same environment due to their sensitivity (Foissner, 1988).

In Yaounde and especially on the Mingoa, several research endeavors have been carried out on the diversity of protozoan communities and their use

in water quality evaluation (Zebaze Togouet *et al*, 2006; Mbondo Biyong, 2013). The present work is aimed at showing the changes in ciliate community structure with respect to water quality in the Mingoa drainage basin.

II MATERIAL AND METHODS

II.1 STUDY SITE

II.1.1 Geographical location

Our study was carried out in the Center region of Cameoon precisely in Yaounde. Yaounde is located in the forest region of the southern plateau between latitudes 3°30'and 3°58'North and longitudes 11°20' and 11°40' East, at an altitude of about 750m (Santoir, 1995). The relief is undulating and extends over several hills high of about 25 to 50 (Bachelier, 1959). This region is characterized by a peculiar equatorial climate called the Yaoundéen climate which is hot and humid and varies slightly over time (Suchel, 1987). It is characterised by an average rainfall of 1576 mm per year, average temperatures of 24.44°C which varies very little. Four unequal seasons which vary from one year to another: a long dry season (mid November to mid March), a short rainy season (mid March to the end of June), a short dry season (July to mid August) and a long rainy season (mid August to mid November) were elucidated (Kuété, 1987). However, the above climatic sequence is seriously perturbed by climate change and global warming. The hydrological network is very dense and consists of the Mfoundi and its affluents.

II.1.2 Sampling stations

Four sampling stations were chosen for our study these include: Mingoa upstream(M1): Located in Camp Sic Messa (Yaounde) at an altitude of 700 m and coordinates N 03˚52'14.8" and E 011˚30'18.1". This station consists of a concrete canal of width 3 m within which water flows. Few macrophytes and a vast diversity of brown and green algae were found here throughout the study period. Water depth at this station was 10 cm with very little sediments. The principal source of pollution in this region comes from domestic wastes which are drained in canalisations emptied in this zone.

Municipal lake: Located at the Yaounde municipal lake at an altitude of 638 m and with coordinates N03˚51'43.7" and E011˚30'42.1". It receives waste waters from the Yaounde central hospital and from households around the station. There was a marked presence of algae and macrophytes all through the period of our study. Here sampling was done at the surface (L1) and 1 m below the surface (L2).

Small lake: Located besides the Yaounde municipal lake at an altitude of 706 m and with coordinates N03˚51'53.9" and E011˚30'32". There was a marked presence of algae and macrophytes all through the study period. Sampling was done at the surface (SL1) and 1m below the surface (SL2).

Mingoa downstream (M2): Located 100 m from the outlet of the municipal lake. It has as geographical coordinates N 03˚52'32.4" and E 011˚30'48.0" is has as altitude 634 m. Water flows through a concrete canal of width 3.7 m where it has a depth 25 cm at the center and 5 cm at the edges. Very few sediments, algae and macrophytes were seen throughout the study period. Construction works were being carried out around this station during part of the study period. Below is a partial view of the different sampling stations.

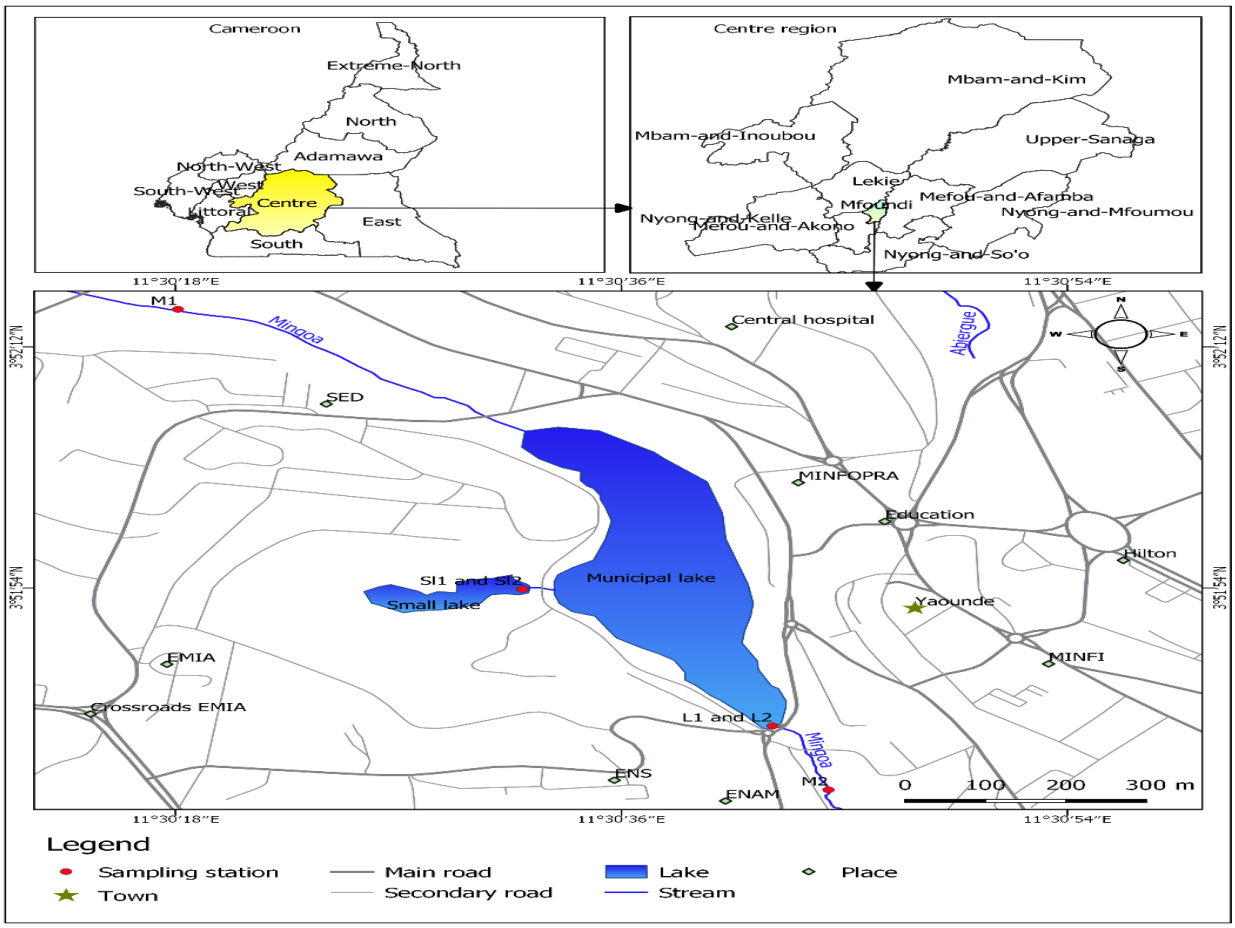

Figure 1: Hydrographic map of the Mingoa drainage basin (Kouam Kenmogne, 2004, modified)

II.2 Measurement of physico-chemical parameters

Physico-chemical analysis was carried out both on the field and in the laboratory of Hydrobiology and Environment of the University of Yaounde 1, following the recommendations of (Rodier, 1996) and (APHA, 2017).

On the field parameters such as temperature (˚C), pH (CU), electrical conductivity (µS/cm), and turbidity (FTU) were measured using appropriate instruments. Oxygen and carbon di oxide were fixed using winkler's reagent for oxygen and sodium hydroxide and phenolphthalein for carbon dioxide. For those carried out in the laboratory, sampling was always done using double capping polyethylene bottles of 250 and 1000mL before being transported to the laboratory in an insulated cooler. Back in the laboratory other parameters such as colour (Pt.Co), suspended solids (mg/L), total dissolved solids (mg/L), carbon dioxide (mg/L) and oxygen (mg/L) were measured.

II.3 Measurement of biological parameters

II.3.1 Sampling of ciliates

Ciliates were collected using the direct method (Sime-Ngando *et al.*, 1990) where the sampling bottle was used to shake then carry water containing ciliates. The ciliates were then transported to the laboratory.

II.3.2 Observation, Identification and counting of ciliates on living samples

Observation, identification and counting were done on living samples. This is because ciliates die rapidly after capture. The water sample was homogenised and 1mL was collected using a calibrated pipette and placed in a Petri dish. The organisms were then identified and counted using a compound light microscope and appropriate identification keys (Dragesco and Njine, 1971); (Dragesco and Dragesco-Kerneis, 1986). Three series of counts were carried out and their average recorded.

Observation was also done after impregnation with ammoniacal silver carbonate (The technic of Augustin *et al.*, 1984). Impregnation is a technic used in the observation of the general structure and the infra-ciliature of ciliated protozoans. It is very effective even on the most

complex species of ciliated protozoans. This technic is however delicate and inconvenient for species of small size. This technic was carried out as follows:

Add 1–2 drops of formalin (about 4 %) and fix for 1–3 min. Mix organisms with formalin by swivelling the slide. Add 1–3 drops of Ferna´ndez-Galiano's fluid to the fixed ciliates, without washing out the formalin, and mix by swivelling the slide for 10–60 s. Place slide on a preheated (60–70uC) hotplate and leave until the drop, which is now rather large, turns goldenbrown (like cognac). Interrupt impregnation by removing the slide from the hotplate and adding a drop of fixative (sodium thiosulfate).

II.4 DATA ANALYSIS

Data analysis was done with the help of the soft wares; Microsoft Excel 2010, and SPSS version 20.0 and past 3. It involved the creation of graphical representations of the results obtained, determination of diversity indices (Shannon and Weaver's diversity index, Pielou's evenness index and Sorenson's similarity index) and correlation tests (Spearmann rank correlation coefficient (r)). The monthly data obtained were used to calculate average seasonal values for our different parameters measured during the short rainy season(from December to March) and the long dry season(from April to July).

III Results and Discussion

III.1 Physico-chemical parameters

The physicochemical parameters varied as follows:

As shown on figure 2, temperature varied very greaty during our study. Temperature values varied fom 25.50 ±0.58°C to 31.13 ± 1.18 °C. This highest value of 31.13 ± 1.18°C was obtained at M1 during the SRS while the least value of 25.50 ±0.58 °C was obtained at L2 during the same season.

Hydrogen potential varied from 7.64 ±0.52CU to 7.83 ± 0.32CU. The highest value was obtained at M1 during LDS while the least value was obtained at SL2 during the SRS.

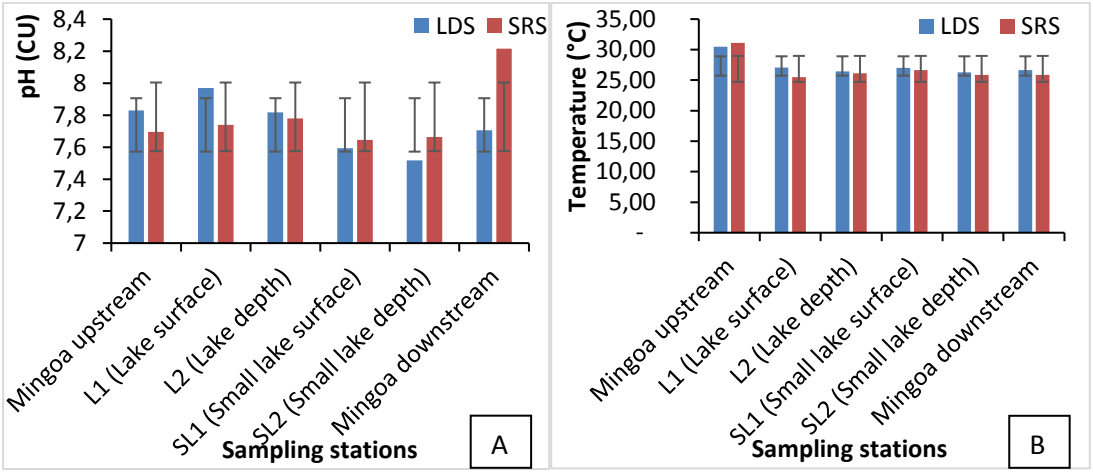

Figure 2: Spatio-temporal variation of pH (A), Temperaature (B))

The waters of the Mingoa showed higher values for dissolved gases (oxygen and carbon dioxide) during the short rainy season compared to during the long dry season (figure 9). Dissolved oxygen varied from 69.25 ± 38.11% to 20.25 ± 10.53%. This highest value of 69.25 ± 38.11% was obtained at M2 during the SRS while the least value of 20.25 ± 10.53 % was obtained at L2 during the LDS. Dissolved carbon dioxide varied from 15.56 ± 4.14mg/L to 9.70 ± 6.50mg/L. This highest value of 15.56 ± 4.14mg/L was obtained at SL2 during the LDS while the least value of 9.70 ± 6.50mg/L was obtained at M1 during the LDS. As shown on figure 3 below, oxidability varied from 5.83 ± 3.50mg/L to 1.89 ± 0.83mg/L. This highest value of 5.83 ± 3.50mg/L was obtained at M1 during the LDS while the least value of 1.89 ± 0.83mg/L was obtained at SL1 during the SRS.

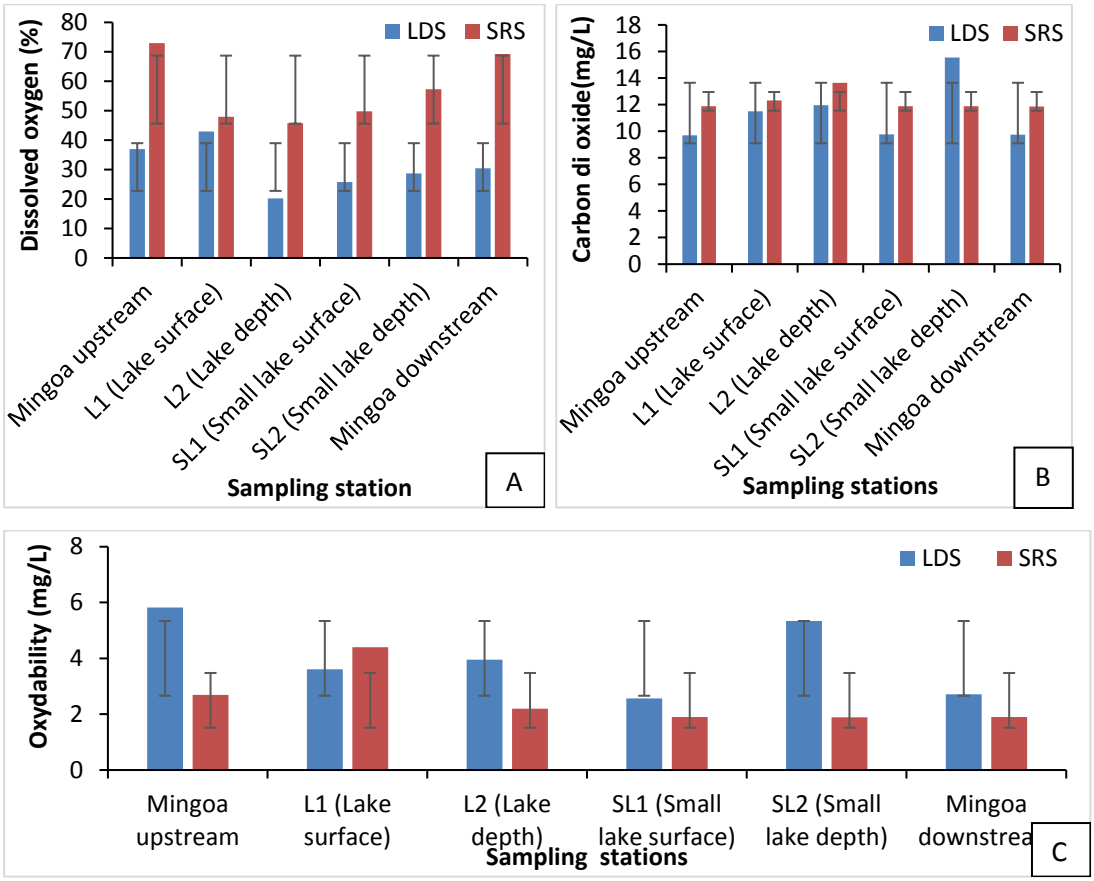

Figure 3: Spatio-temporal variation of Dissolved Oxygen (A) and Carbon dioxide (B) and Oxidability(C)

Values of total dissolved solids and conductivity followed the same trend during our study period (figure 4 A and B). TDS varied from 208.25 ± 118.52 mg/L to 71.50 ± 12.48 mg/L. This highest value of 5.83 mg/L ± 3.49 mg/L was obtained at M1 during the short rainy season (SRS) while the least value of 71.50 ± 12.48 mg/L was obtained at SL2 during the short rainy season (SRS). Conductivity values varied from 416.00 ± 235.88 µS/cm and 143.00 ± 25.23 µS/cm. This highest value of 416.00 ± 235.88 µS/cm was obtained at M1 during the SRS while the least value of 143.00µS/cm ± 25.23 µS/cm was obtained at SL2 during the short rainy season (SRS).

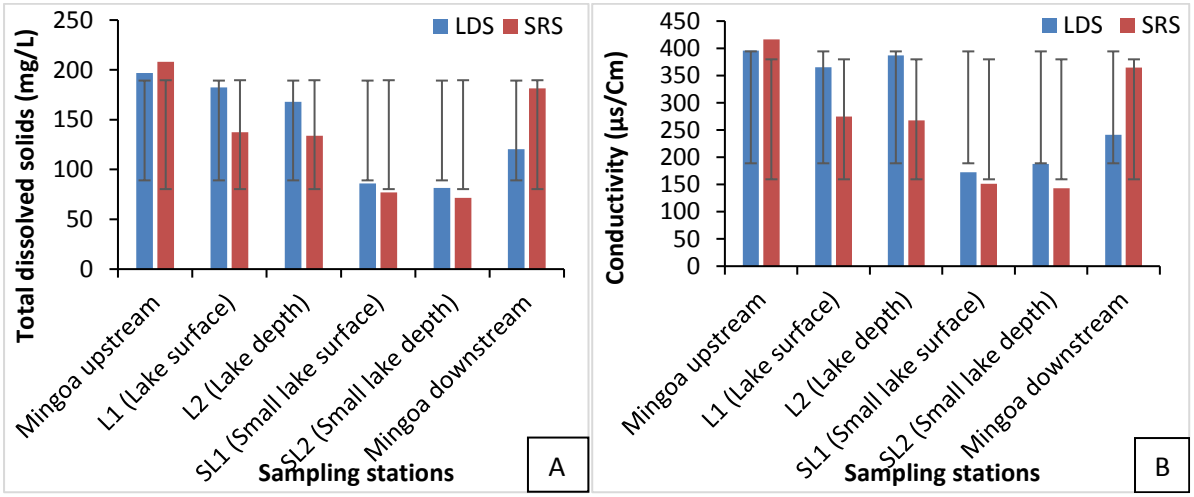

Figure 4: Spatio temporal variation of TDS (A) and Conductivity(B)

Suspended solids, Colour and Turbidity showed a similar trend in variation, with values obtained during the long dry season being higher in most of the stations than those of the short rainy season (figure 5).

Suspended solids varied fom 77.50 ± 55.30 mg/L to 16.80 ± 10.90 mg/L. This highest value of 77.50 ± 55.30 mg/L was obtained at SL2 during the SRS while the least value of 16.80 ± 10.90 mg/L was obtained at M1 during the LDS.

Colour varied from 234.50 ± 184.10 Pt.Co to 97.3 ± 118.20 Pt.Co This highest value 234.50 ± 184.10Pt.Co of was obtained at L2 during the LDS while the least value of 97.30 Pt.Co ± 118.20 Pt.Co was obtained at M1 during the short rainy season (SRS).

Turbidity varied from 68.00 ± 41.58FTU to 13.00 ±8.76 FTU. This highest value of 68.00 ± 41.58FTU was obtained at L1 during the LDS while the least value of 13.00 ±8.76 FTU was obtained at M1 during the SRS.

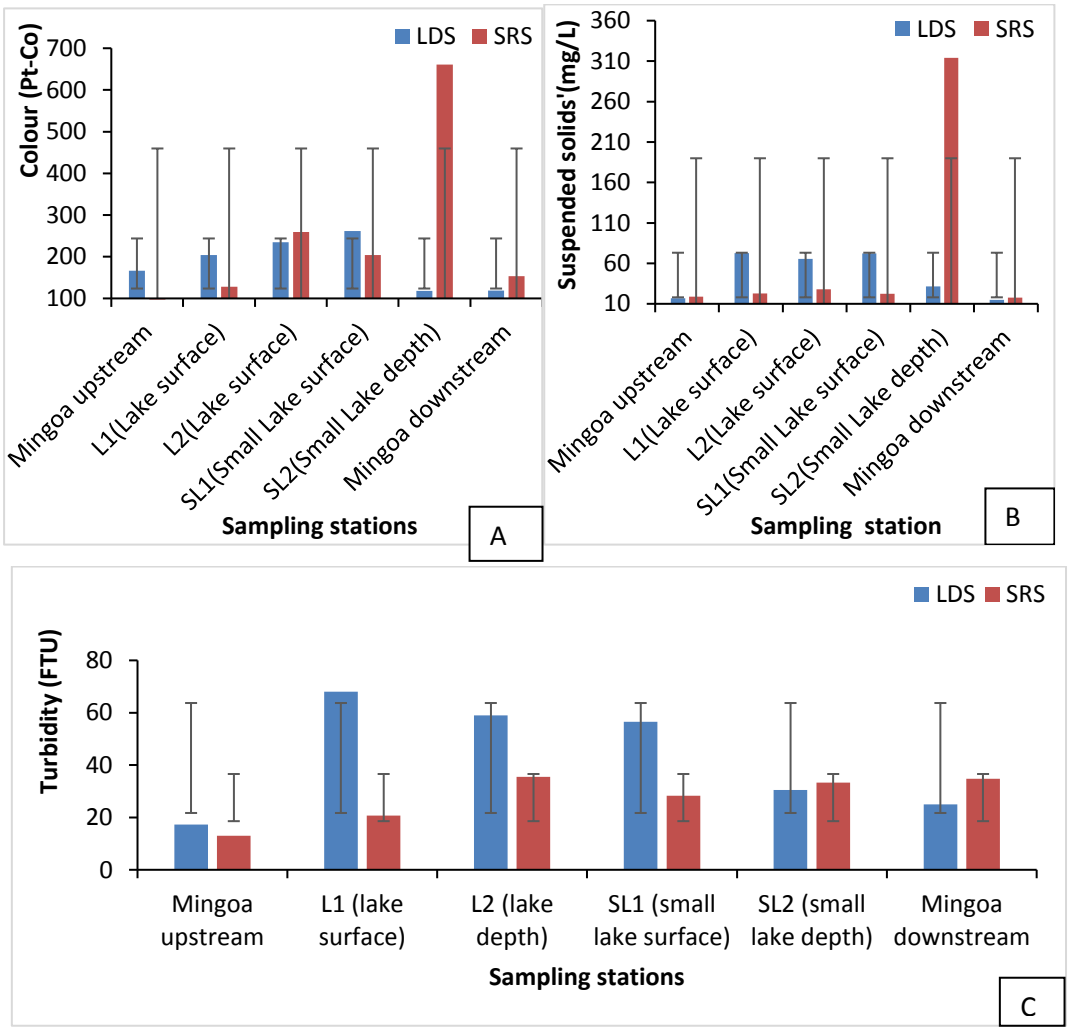

Figure 5: Spatio-temporal variation of Colour(A), Suspended Solids (B) and Turbidity(c)

Nitrates varied from 24.13 ± 6.66mg/L to 2.58 ± 60.64 mg/L. This highest value of 24.13 ± 6.66mg/L was obtained at M2 during the short rainy season SRS while the least value of 2.58 ± 60.64 mg/L was obtained at M1 during the SRS (figure 6A).

The waters of the Mingoa have very high levels of orthophosphates. Orthophosphates values varied from 7.53 ± 4.04mg/l to 0.57 ± 0.66 mg/l. This highest value of 7.53 ± 4.04mg/l was obtained at L2 during the SRS while the least value of 2.575 ± 60.64 mg/l was obtained at SL2 during the LDS. (figure 16B).

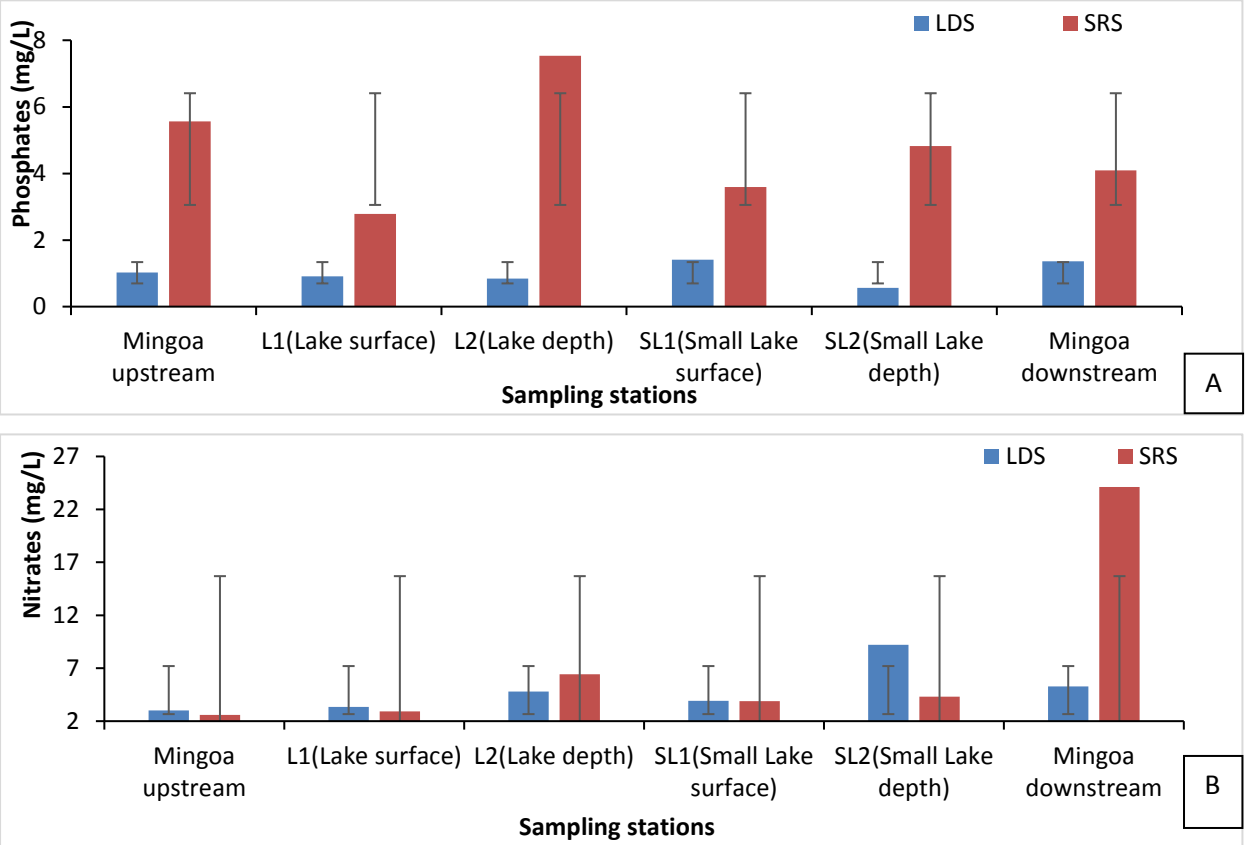

Figure 6: Spatio-temporal variation of Nitrates (A) and Orthophosphates (B)

III.2 Biological parameters

III.2.1 Spatio-temporal variation of biological parameters during the study period.

III.2.1.1Abundance variation of ciliate community

During our study 4598 ciliates were sampled and identified. These ciliates belong to 3 classes, 10 orders, 22 families, 27 genera and 34 species. The Class of Oligohymenophora was numerically dominant with a relative abundance of 51.54% and represented by 3 orders, 8 families,10 genera and 12 species. It is followed by the class of Kinetophragminophora with a relative abundance of 29.27% and represented by 5 orders, 7 families, 9 genera and 11 species. The class of Polyhymenophora was the least represented with a relative abundance of 19.18% and represented by 2 orders, 7 families, 8 genera and 12 species (figure 7).

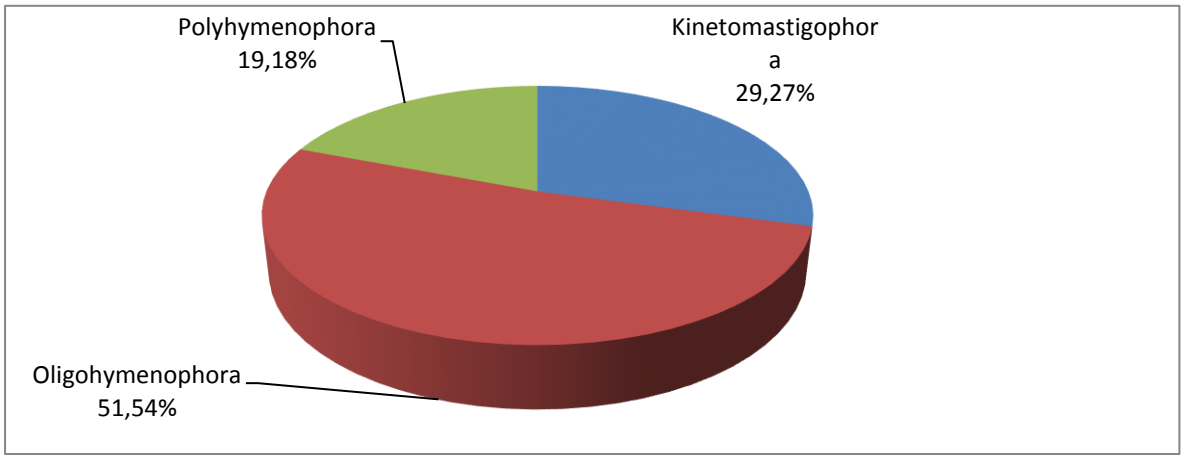

Figure 7: Relative abundance of ciliate classes

From table 1 we can see that the order of Hymenostomatida was the most abundant and represented while the order of Nassulida was the least abundant and together with orders Pleurostomatida, Karyorectilida, Colpodida, Sessilida and Scuticociliatida the least represented.

Table 1: Relative abundance of ciliate orders

Order	Relative Abundance
Hymenostomatida	43.35%
Heterotrichida	13.79%
Karyorectilida	9.33%
Prostomatida	9.03%
Colpodida	7.00%
Hypotrichida	5.39%
Pleurostomatida	3.59%
Scuticociliatida	3.28%
Sessilida	2.91%
Nassulida	0.33%

The family of Neobursaridae was the most abundant while stentoridae was the least abundant. The families of Stentoridae, Euplotidae, Prorodontidae, Colepidae, Colpodidae, Nassulidae, Tetrahymenidae, Frontinidae, Urocentridae, Lembadionidae, Spirostomidae, Caenomorphidae and Spirofilidae were the least represented (table 2).

Table 2: Relative abundance of ciliate families

Family	Relative abundance
Neobursaridae	14.62%
Paramecidae	12.61%
Metopidae	9.83%
Loxodidae	9.33%
Colpodidae	7.00%
Urocentridae	6.98%
Prorodontidae	6.33%
Frontinidae	5.81%
Tetrahymenidae	4.09%
Oxytrichidae	3.96%
Amphileptidae	3.59%
Uronematidae	3.28%
Vorticelidae	2.91%
Caenomorphidae	2.89%
Trachelidae	2.41%
Spirofilidae	1.28%
Lembadionidae	1.24%
Spirostomidae	1.00%
Nassulidae	0.33%
Colepidae	0.28%
Euplotidae	0.15%
Stentoridae	0.07%

Table 3 shows *Neobursaridium gigas* was the most abundant species while *stentor* sp the least.

Table 3: Abundance and relative abundance of ciliate species sampled during the study period

Ciliate species	Relative abundance
Prorodon ovalis	6.33%
Coleps hirtus	0.28%
Dileptus anser	1.65%
Dileptus sp	0.37%
Paradileptus elephantinus	0.39%
Amphileptus quadrinucleatus	1.59%
Litonotus sp	2%
Loxodes rex	5.87%
Loxodes kahli	3.46%
Colpoda cucullus	7%
Nassula aurea	0.33%
Colpidium sp	4.09%
Paramecium africanum	5.98%
Paramecium caudatum	4.20%
Paramecium sp	2.44%
Frontania leucas	5.81%
Urocentrum turbo	6.98%
Neobursaridium gigas	13.11%
Neobursaridium sp	1.50%
Lembadion Leucens	1.24%
Uronema acutum	2.35%
uronema sp	0.94%
Vorticella campanula	2.91%
Spirostomum ambigum	1.00%
Metopus sp	4.28%
Metopus ovatus	5.55%
Stentor sp	0.07%
Caenomorpha medusula	2.89%
Hypotrichidium africanum	1.28%
Oxytricha chlorelligera	0.37%
Pleurotricha lanceolata	1.26%
Histriculus muscorum	1.48%
Stylonicha putrina	0.85%
Euplotes patella	0.15%

III.2.1.2 Spatial variation of ciliate abundance

As shown on table 4, *Loxodes rex, loxodes kahli, Colpoda cucullus, Paramecium africanum, Urocentrum turbo,Vorticella* sp*, Metopus ovatus, metopus* sp and *caenomorpha medusala* were the most widely distributed found at all of our sampling stations while *coleps hirtus* was the least distributed found at only one station.

At Mingoa upstream, a total of 27 species were sampled and the average abundance per species ranged from 1 to 16 Ind/mL. The most abundant species were, *Loxodes rex* with 16 Ind/mL, *Paramecium caudatum* with10 Ind/mL and *paramecium africanum* with 10 Ind/mL While the least abundant species were *Prorodon ovalis, Dileptus anser, Paradileptus elephantinus,Amphileptus quadrinucleatus, Nassula aurea, Frontonia leucas, Lembadion leucens, Spirostomum ambigum, caenomorpha medusala, Hypotrichidum africanum, Oxytricha sp* and *Pleurotricha lanceolata each with only 1 individual per millilitres.* Species such as *Neobursaridium gigas, Neobursaridium* sp, *Coleps hirtus, Stentor* sp, *Oxytricha chlorelligera, Histriculus muscorum, Stylonicha purina* and *Euplotes patella* were totally absent at this station.

At the surface of the municipal lake, a total of 32 species were sampled and the average abundance of each species ranged 1 to 62 Ind/mL. The most abundant species were *Neobursaridium gigas* with 62 Ind/mL, *Frontonia leucas* with 21 Ind/mL, *Prorodon ovalis* with 18 Ind/mL, *Urocentrum turbo* with 11 Ind/mL and *Metopus ovatus* with 10 Ind/mL, while the least abundant species *were Coleps hirtus, Paradileptus elephantinus, Dileptus* sp, *Uronema acutum, Uronema* sp, *Hypotrichidium africanum, stentor* sp, and *oxytricha chlorelligera* each with 1 Ind/mL. Species such as *Nassula aurea, Stentor sp, Spirostomum ambigum* and *Euplotes patella* were totally absent at this station.

At the bottom of the municipal lake, a total of 25 species were sampled and the average abundance of each species ranged from 1 to 15 of Ind/mL water .The most abundant species were *Prorodon ovalis* with 15 Ind/mL,*Colpoda cucullus* with 7 Ind/mL,*Colpidium sp* with 8 Ind/mL,*Urocentrum turbo* with 6 Ind/mL and *Metopus ovatus* with 7 Ind/mL. While the least abundant species *were Stylonicha purina, Histriculus muscorum, Pleurotricha lanceolata, Dileptus anser, Hypotrichidium africanum, Spirostomum ambigum, Lembadion leucens, Frontonia leucas, Amphileptus quadrinucleatus, Neobursaridium gigas* and *Neobursaridium* sp each with 1individual per milliliter of water. Species such as *Coleps hirtus, Paradileptus elephantinus, Dileptus* sp, *Paramecium caudatum, Litonotus* sp *Uronema acutum, Uronema* sp , *Nassula aurea, Stentor* sp, *Oxytricha chlorelliger and Euplotes* patella were totally absent at this station.

At the surface of the small lake, a total of 32species were sampled and the average abundance of each species ranged from 1 to 12 . The most abundant species were *Colpoda cucullus* with 5 Ind/mL, *Litonotus sp* with 6 Ind/mL, *Amphileptus quadrinucleatus* with 5 Ind/mL, *Frontonia leucas* with 9 Ind/mL, *Neobursaridium gigas* with 12 Ind/mL, *Urocentrum turbo* with 8 Ind/mL and *Caenomorpha medusala* with 5 Ind/mL.While the least abundant species were *Histriculus muscorum, Dileptus sp, Spirostomum ambigum, Euplotes patella, Oxytricha chlorelligera, Neobursaridium sp, Paramecium caudatum, Paramecium sp ,Nassula aurea,Loxodes rex, Paradileptus elephantinus, and Coleps hirtus* each with 1individual per milliliter of water. Species such as Stentor sp and stylonicha sp were totally absent at this station.

At the bottom of the small lake, a total of 26species were sampled and the average abundance of each species ranged from 1 to 9 Ind/mL. The most abundant species were *Colpoda cucullus* with 9 Ind/mL, *Urocentrum turbo* with 4 Ind/mL, *Loxodes rex,* with 5 Ind/mL and *Loxodes kahli* with 6 Ind/mL. While the least abundant species were *Histriculus muscorum, Paradileptus elephantinus, Spirostomum ambigum,Neobursaridium gigas,Vorticella campanula Uronema* sp ,*Prorodon ovalis Dileptus anser, Stentor sp ,Caenomorpha medusala , Pleurotricha lanceolata Oxytricha chlorelligera, stylonicha purina* and *Uronema acutum* each with 1individual per milliliter of water. Species such as *Coleps hirtus,Dileptus sp,Amphileptus quadrinucleatus, Litonotus sp, Neobursaridium sp,Nassula aurea,Colpidium sp*,and *Euplotes patella'* were totally absent at this station.

At Mingoa downstream, a total of 27 species were sampled and the average abundance of each species ranged from 1 to 12. Ind/mL The most

abundant species were *Paramecium caudatum* with 6 Ind/mL, *paramecium africanum* with 12 Ind/mL, *Metopus ovatus* with 6 Ind/mL, *Vorticella campanula* with 5 Ind/mL,*Urocentrum turbo* with 7 Ind/mL and *Colpoda cucullus* with 8 Ind/mL. While the least abundant species *were Coleps hirtus, Dileptus* sp, *Amphileptus quadrinucleatus, Litonotus* sp, *Colpidium* sp, *Prorodon ovalis, Loxodes kahli, Uronema sp, Nassula aurea, Pleurotricha lanceolata, Hypotrichidum africanum, Oxytricha chlorelligera* and *Stylonicha purina* with only 1 individual per millilitres. Species such as ,*Frontonia leucas, Paradileptus elephantinus, Neobursaridium gigas, Neobursaridium sp, Lembadion leucens, Stentor sp* and *Euplotes patella* were totally absent at this station

Table 4: Spatial variation of ciliate abundance in individuals per milliliter

Sampling stations	M1		L1		L2		SL1		SL2		M2	
Ciliate species	Mean	Sdv	Mean	Sdv	Mean	Sdv	Mean	Sdv	Mean	Sdv	Mean	Sdv
Prorodon ovalis	1	1	18	10	15	8	2	7	1	6	1	5
Coleps hirtus	0	0	1	1	0	1	1	1	0	1	1	1
Dileptus anser	1	1	4	2	1	1	2	1	1	1	2	1
Dileptus sp	0	0	1	1	0	1	1	1	0	1	0	1
Paradileptus elephantinus	1	1	1	1	0	1	1	1	1	1	0	1
Amphileptus quadrinucleatus	1	2	2	1	1	1	5	1	0	1	1	1
Litonotus sp	2	3	3	1	0	1	6	2	0	2	1	2
Loxodes rex	16	31	7	12	2	11	1	10	5	10	4	3
Loxodes kahLi	5	9	4	3	2	3	2	3	6	3	1	1
Colpoda cucullus	6	18	6	7	7	5	5	5	9	4	8	2
Nassula aurea	0	1	0	1	0	1	1	1	0	1	1	1
Colpidium sp	2	5	10	4	8	3	2	3	0	3	1	2
Paramecium africanuum	10	19	4	8	4	6	3	6	2	6	12	3
Paramecium caudatum	10	11	5	3	0	5	1	4	2	3	6	2
Paramecium sp	6	14	3	6	3	5	1	4	2	4	1	2
Frontania sp	1	1	21	11	1	9	9	8	3	7	0	4
Urocentrum turbo	5	4	11	4	6	3	8	3	4	3	7	2
Neobursaridium gigas	0	0	62	35	1	28	12	23	1	22	0	13
Neobursaridium sp	0	0	8	4	1	3	1	3	0	3	0	2
Lembadion Leucas	1	2	2	1	1	1	2	1	2	1	0	1
Uronema acutum	6	10	1	4	0	4	3	3	1	3	3	1
uronema sp	2	2	1	1	1	1	2	1	1	1	1	1
Vorticella campanula	2	5	3	2	4	2	2	1	1	2	5	1
Spirostomum ambigum	1	1.	1	1	1	1	1	1	1	1	2	1
Metopus sp	4	4	9	3	5	2	2	2	2	2	2	1
Metopus ovatus	4	4	10	3	7	3	3	3	2	3	6	2
Stentor sp	1	1	1	1	0	1	0	1	1	1	0	1
Caenomorpha medusula	1	1	4	2	3	1	5	2	1	1	2	1
Hypotrichidium africanum	1	1	1	1	1	1	3	1	2	1	1	1
Oxytricha chlorelligera	1	1	0	1	0	1	1	1	0	1	1	1

Pleurotricha lanceolata	1	1	2	1	1	1	3	1	0	1	1	1
Histriculus muscorum	0	0	2	1	1	1	1	1	1	1	4	1
Stylonicha putrina	0	0	3	1	1	1	0	1	1	1	1	1
Euplotes patella	0	0	0	0	0	0	1	1	0	1	0	0

III.2.1.3 Seasonal variation of ciliate abundance

As seen on table 5, during the LDS, 33 species of ciliates were sampled. The average abundance of this species varied from 1 to 69 Ind/mL. The most abundant species were *Prorodon ovalis* with 69 Ind/mL *Colpoda cucullus* with 64 Ind/mL, *Metopus ovatus* with 59 Ind/mL *Paramecium africanum* with 57 Ind/mL *and Loxodes rex* with 50 Ind/mL, while the least abundant species *were Euplotes patella* and *Neobursaridium sp* both with 1 individual per milliliter. The species *Nassula aurea* was totally absent during this season.

During the SRS, 32 species of ciliates were sampled. The average abundance of this species varied from 1 to 107 individuals per millilitre of water.The most abundant species were *Neobursaridium gigas* with 107 Ind/mL, *Frontonia leucas* with 47 Ind/mL, *Urocentrum turbo* with 36 Ind/mL *Caenomorpha medusala* with 22, Ind/mL *Paramecium caudatum* with 20 Ind/mL *Loxodes rex* with 18 Ind/mL, *Colpoda cucullus* with 17 Ind/mL and *Neobursaridium* sp with 16 Ind/mL, while the least abundant species was *Euplotes patella* with 1 individual per milliliter.The species *Coleps hirtus* and *stentor* sp were totally absent during this season.

Table 5: Seasonal variation of ciliate abundance in individuals per milli liter

Seasons	LDS		SRS	
Ciliate species	Mean	Sdv	Mean	Sdv
Prorodon ovatis	12	30	1	2
Coleps hirtus	1	2	0	0
Dileptus anser	2	3	2	3
Dileptus sp	1	1	1	1
Paradileptus elephantinus	1	1	1	1
Amphileptus quadrinucleatus	2	6	1	2
Litonotus sp	2	4	2	6
Loxodes rex	8	19	3	8
Loxodes kahLi	4	8	3	4
Colpoda cucullus	11	15	3	6
Nassula aurea	0	0	1	2
Colpidium sp	7	15	1	5
Paramecium africanuum	9	18	2	4
Paramecium caudatum	5	10	3	6
Paramecium sp	3	8	1	2
Frontania sp	3	6	8	22
Urocentrum turbo	7	9	6	7
Neobursaridium gigas	7	27	18	52
Neobursaridium sp	1	1	3	10
Lembadion Leucas	1	2	2	3
Uronema acutum	3	7	2	3
Uronema sp	1	2	1	2
Vorticella campanula	5	6	1	2

Spirostomum ambigum	1	3	1	1
Metopus sp	7	12	1	3
Metopus ovatus	10	14	1	1
Stentor sp	1	1	0	0
Caenomorpha medusula	2	4	4	8
Hypotrichidium africanum	1	1	2	4
Oxytricha chlorelligera	1	1	1	2
Pleurotricha lanceolata	2	3	1	1
Histriculus muscorum	2	4	1	2
Stylonicha putrina	1	3	1	2
Euplotes patella	0	1	1	1

Spatially, the Shannon and Weaver index varied from 2.624 bits per individuals at station L1 to 3.058 bits individuals obtained at SL1 thus indicating that station SL1 had the highest specific diversity while station M1 had had the least specific diversity. Pielou's equitability index varied from 0.7875 individuals per bit at L1 to 0.9084 individuals per bit obtained at SL2 thus indicating that individuals were most evenly distributed at SL2 and least evenly distributed at L1.

Temporally, the Shannon and weaver index varied from 2.886 individuals per bit during the SRS to 3.044 individuals per bits obtained during the LDS indicating that the specific diversity was higher during the LDS than during the SRS.

Pielou's equitability index varied from 0.8328 individuals per bit during the SRS to 0.8706 individuals per bit during the LDS thus indicating that individuals were most evenly distributed during the LDS and least evenly distributed during the SRS.

SÖrenson's similarity index shows a marked similarity between our different sampling stations with the greatest similarity being between M1 and SL2 with a similarity index of 98% and the least similarity being between SL2 and M2 with a similarity index of 79%.

Spearman's correlation test shows a strong correlation between some physico-chemical parameters and the abundance of some species of ciliates examples include; a positive correlation between carbon dioxide and the abundance of *Litonotus* sp and *Colpidium* sp (r=0.41 and p=0.00) and (r=0.37 and p= 0.01) respectively. A positive correlation between oxidability and the abundance of *Paradileptus elephantinus* (r= 0.41 and p= 0.00). A positive correlation between salinity and the abundance of *Paradileptus elephantinus* (r=0.37 and p=0.01) and *Colpoda cucullus* (r=0.91 and p=0.00). A negative correlation between conductivity and the abundance of *Litonotus* sp (r=0.87 and p=0.00) and *Nassula aurea* (0.87 and p=0.00). A negative correlation between turbidity and *Uronema acutum* (r=0.371 and p=0.01). A negative correlation between *Metopus ovatus* and resistivity (r=0.37 and p=0.01) and phosphates (r=0.57 and p=0.00) and a positive correlation with alkalinity (r= 0.372 and p=0.01) respectively.

There was also strong correlations between the abundance of some ciliate species examples include; a positive correlation between *Paradileptus elephantinus*, and *Litonotus* sp (r= 0.41 and p= 0.00) respectively.A positive correlation beteween *Colpoda cucullus* and *Loxodes rex* (r= 0.89 and p=0.00).

There was also strong correlations between some physico-chemical parameters such as a positive correlation between oxidability and CO_2 (r= 0.41 and p= 0.04), turbidity and colour (r=0.39 and 0.01), suspended solids and colour (r=0.57 and p= 0.00) and a negative correlation between salinity and and resistivity (r=0.80 and p= 0.00)

Kruskal wallis test showed no statistical difference between the values of the physico-chemical parameters on one part and ciliate abundance on the other measured during the LDS and SRS with all p values calculated being greater than 0.05. There was however a statistical difference (p<0.05) between the values of pH, dissolved oxygen, dissolved carbon dioxide, alkalinity, oxidability, orthophosphates and ciliate abundance measured at the different sampling stations.

IV DISCUSSION

IV.1 Physico-chemical parameters

Average temperatures recorded varied very little and were not very different from those obtained by Mbondo (2013) on the Mingoa river basin and are typical of the climate of Yaounde (Suchel, 1988). Concerning this, Lietchi *et al.,* (2004) declared that the temperature of surface water is linked to that of the environment.

Values for water colour and turbidity were relatively high all through the study period and were quite similar to those obtained by Zébaze Togouet (2006) on the municipal lake which is part of the Mingoa drainage basin. It could be due to the introduction of wastes into the drainage basin as indicated by the high levels of orthophosphates (between 7.53 ± 4.04mg/L and 0.57 ± 0.66 mg/L) recorded during the study period. Concerning this, Jenny (2018) declared that in aquatic environments the presence in high quantities of phosphates indicates pollution by industrial and domestic wastes.

The slightly basic nature of the waters of the Mingoa drainage basin during the study period could be justified by the high alkalinity values recorded (between 37.50 ± 18.646mg/L and 14.50 ± 18.646mg/L. This alkalinity values were similar to those obtained by Tabue *et al* (2012) on thesame dranaige basin. This high alkalinity could be due to the introduction of basic wastes into the water body but also due to the high values of dissolved CO_2 recorded (between 15.56 ± 4.12mg/L and 9.70 ± 6.495mg/L). Concerning this Tabue *et al* (2012) declared that high values of bicarbonates in water result from the hydrolysis of carbon dioxide.

The waters of the Mingoa were averagely oxygenated. This is similar to those obtained by Ebang *and coll.* (2012) on the Mfoundi river also found in an urban region. This values could be due to the mineralisation of organic matter. The higher values of dissolved oxygen obtained during the SRS could be due to more intense water oxygenation resulting from water agitations during periods of rainfall (Baldy *et al.,* 1995).

IV.2 Biological parameters

This study enabled the sampling of 34 species of ciliated protozoans which is very similar to the 32 species sampled by Foto Menbohan (1998) on 2 polluted water bodies in Yaounde, and 32 species sampled by Ajeagah *and coll.* (2013) in the obili lake in Yaounde, Cameroon both of which are subject to similar stress due to pollution from human activities like it is the case with the Mingoa. This is however lower than the 43 species sampled by Djeufa (2008) on the river Nga located in a peri urban zone.

The 34 species sampled is quite small for waters subject to pollution and undergoing eutrophication. This is in line with conclusions made by Dragesco (1973) on the low specific diversity of ciliate communities in tropical regions. The resemblance between the ciliate community of the Mingoa and those reported in other hydrosystems in Cameroon (Foto Menbohan, 1989 and Djeufa, 2008) suggests the cosmopolitan distribution of most of the ciliates sampled.

The difference in ciliate abundances between the LDS and the SRS was not significant this could be due to the fact there was no significant difference in the physico-chemical parameters of water during our study period. Concerning this Ebang *et al* (2012) declared that the seasonal variation of some groups of aquatic organisms is not marked. Their distribution being influenced more by water quality along a river.

As seen on table 3 above, ciliate abundance was highest at the littoral of the Municipal Lake this could be explained by the presence of numerous microhabitats (herbaceous strata bordering the lake, surface water plants, numerous suspended solids upon which ciliates fixe themselves on. It could also be due to an abundance of food resources. Concerning this, Wilbert (1969) showed that a large majority of ciliate species live all through the year but their density depends on the quantity of food and dissolved oxygen. The least abundance was at the bottom of the small lake this could be due to the reduced number of micro habitats, but also due to shortages in food resource, and dissolved oxygen.

The relatively high frequency of some species observed in the Mingoa has also been observed in other highly degraded streams of the Mfoundi drainage basin (Foto Menbohan *and al*., 2011). These high frequencies are similar to those obtained by Zébaze Togouet (2006) on the Yaounde municipal lake and could be due to pollution by organic matter as shown by the high abundance of genera such as *Urocentrum, Paramecium, Frontonia* and *Colpoda* which are polluo-resistant and are bio indicators of organic pollution (Foissner, 1998) and indicates the mesotrophic nature of these waters. It could also be due to their omnivorous diet enabling them to feed on a large range of food resources this is the case with *Frontonia leucas*. It could also be explained by their complex buccal cavity made up of a peristome, cytostome, and

infundibulum. This facilitates the exploitation of food resources from the environment. These organisms also have powerful trichocysts used for protection and prey capture this reduces the pressure due predation but also increases food availability. It could also be due to the presence of enzymatic contents which are adapted for the assimilation of organic matter present in these waters (Ajeagah *et al.,* 2010). Species such as *Neobursaridium gigas* have powerful collector canals around their contractile vacuole this facilitates the evacuation of wastes and excess water from the cell thus increasing its chances of survival in the aquatic environment.

The relatively small number of species obtained could be due to the relatively high water temperatures recorded during the study period. Foto menbohan *et al* (2006) showed that water temperatures between 22.4°C and 26.5°C are considered hot. Concerning this, Dragesco (1986) declared that the relative poverty in specific diversity of African inter tropical ciliates is most probably due to high temperatures which only few species of ciliates are able to adapt to.

CONCLUSION

At the end of our work we arrived at the facts that the waters of the Mingoa river basin were averagely oxygenated, slightly alkaline with pH values close to neutrality. It was also noted that the waters of the Mingoa river basin were also undergoing eutrophication as indicated by the high values of orthophosphates recorded during the period of study and also due to the presence in large numbers of ciliates indicators of organic pollution.

The ciliate community of the Mingoa river basin is averagely diversified and evenly distributed. Four thousand five hundred and ninety eight ciliates were sampled. This ciliates belonged to 3 classes, 10 orders, 22 families, 27 genera and 34 species. The class of Oligohymenophora was the most represented with 3 orders, 8 families, 10 genera and 12 species Order Hymenostomatida was the most abundant but also the most represented. Oxytrichidae was the most represented family and Neobursaridae the most abundant family. *Neobursaridium* was the most abundant genus and *Neobursaridium gigas* was the most abundant species together with species such as *Urocentrum turbo, Prorodon ovalis, Metopus ovatus, Frontania sp,Colpoda cucullus, Loxodes rex* and *Paramecium africanum.*

Ciliate abundance was relatively high for some species and the number of species present relatively low which is characteristic of waters with high levels of organic pollution. Also noted was a spatial variation of abundances with respect to physico-chemical factors such as dissolved oxygen, and organic matter. No significant difference was noted between values of physico-chemical parameters on one part and ciliate abundances on the other part obtained during the different seasons.

The marked presence of genera such as *Neobursaridium, Paramecium, Urocentrum and Frontonia* are indicative of the mesotrophic state of these waters.

REFERENCES

Ajeagah G. A., Njine T., Foto S.M., Nola M., Heller L. 2010. Impact of a brewery effluent on the ecological characteristics of an urban stream (Cameroon*). International Journal of geotechnics and environmen*t 2(1): 55-69.

Ajeagah G. A., Bikitbe J. F., Longo F. 2013. Qualité bioécologique d'un milieu lacustre hyper-eutrophisé en zone équatoriale. *Afrique Science*, 9(2) : 50-66.

APHA., AWWA., WEF. 2017. Standard method for examination of water and wastewater 20th edition. *American Public Health Association* Washington D.C.1150p.

Augustin, H., Foissner, W. & Adam, H. (1984). An improved pyridinated silver carbonate method which needs few specimensand yields permanent slides of impregnated ciliates (Protozoa,Ciliophora).Mikroskopie41, 134–137.

Bachelier G. 1959. Etude pédologique des sols de Yaoundé ; Contribution à l'étude de la pédogenèse des sols férralitique. *Agronomie Tropicale*. XIV: 279-305.

Barbour M.T.,Gerritsen .J.,Stribling.J.b.(1991). Rapid bioassessment protocols for use in streams and wadeable rivers:Benthic macroinvertabrates and fish, Second edition (Report). Washington DC.:US.Environmental protection agency.EPA 841-B-99-002.

Cairns J. Jr., Lanza G. R., Parker B. C. 1972. Pollution related Structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Pr. *Académie Nationale des Sciences de Philadelphie*, (124): 79-127.

Ebang D.M., zébaze Togouet S.H., Foto Menbohan S., Kemka N.,Nola M., Boutin C., Nguetsop M.D. et Njine T. 2012. Bio-écologie des diatomées épilithiques de la riviére Mfoundi (Yaoundé, Cameroun): Diversité, Distribution Spatiale et Influence des Pollutions Organique. *Revue Des Sciences De L'Eau*. 25(3): 203-218.

Debashree S. 2017. Importance of water to living organisms. *Bizfluent*. Retrieved from https//bizfluent.com/about -6453252-importance-water-living-organisms.html.

Djeufa H.G. 2008 Structure du peuplement des protozoaire cilies dans le cour d'eau Nga. *Memoire de DEA. Universite de Yaounde 1*, 73p.

Dragesco J., Dragesco Kerneis A .1986. Ciliés libre de l'afrique intertropical: Introduction á la connaissance de l'études des ciliés. *ORSTOM, Faune Tropical XXVI, Paris* ,559p.

Dragesco J., Njine T. 1971. Complement a la connaisance des Ciliés libre du cameroun. *Ann. Fac. Sci. Cameroun*, (78): 79-140.

Dragesco J. 1973. Quelques données écologiques sur les ciliés libre de l'afrique. *Amer Zoologist*, (13): 231-232.

Foto Menbohan S. 1989. Etude de la qualité de la pollution de 2 cours d'eaux á Yaoundé: l'Abiergué,et le Mfoundi: Etudes physico-chimique et biologique. *Thèse de Doctorat 3e cycle, Université de yaounde 1, Cameroun, 142p*.

Foto Menbohan.S., Njiné T. 1998. Distribution et dynamic des population des ciliés dans deux cours d'eaux Urbain: l'abiergué,et le Mfoundi Etude de la qualité de la pollution de 2 cours d,eaux á Yaoundé: L'Abiergué,et le Mfoundi. *Ann. Fac. sci, Univ. Yaoundé 1, Série Science Naturelle et Vie*, 34: 269- 279.

Foto Menbohan.S., Njiné T., Zebaze T. S. H., Kemka N., Nola M., Monkiedjeu et Boutin C. 2006. Distribution du zooplancton dans un reseaux hydrographique perturber en m illieu urbain tropical (Cameroun*). Bull. Soc. Nat. Toulouse*, 142: 53-62.

Foto Menbohan S., Zebaze Togouet S. H., Ajeagah Gideon A., Nzieleu Tchapgnouo G.J.,Njiné T. 2011. Ciliates community distribution and saprobic evaluation of an urban hydrosystem: The Biyeme stream Cameroon (Central Africa). *Journal of Applied Biosciences*, 48: 3306 – 3315.

Foissner W.1988. Taxonomic and nomenclatural revision of Sladececk's list of ciliates (Protozoa: Ciliophora) as indicators of water quality. *Hydrobiologica*, 166:1-64.

Jenny G. 2018. How do phosphates affect water quality?. Retrieved from https// Sciencing.com/-Phosphates-affect-water-quality-4565075.html.

Kuété M. 1987. Etude géomorphologique du massif de Yaoundé. *Thèse de doctorat 3e Cycle Université de Bordeaux*, 279p.

Liechti P., Frutiger A., Zobrist N. 2004. Méthodes d'analyse et d'appréciation des cours d'eau de suisse. Module chimie, analyse physico chimique de niveau R et C. *OFEFP Berne*, 12p

Mbondo B. S. R. 2013. Dynamique d'abondance des kystes d'amibes enteropathogenes dans les eaux usees et de surface:cas du basin versant du Mingoa (Yaoundé). *Memoire de Master Univiversité Yaoundé 1,49p.*

Neveu A., Riou C., Bonhomme R., Chassin P., Papy F. 2001. L'eau dans l'espace rural. *Vie et Milieux Aquatique, INRA. Paris*. 286p.

Rodier J. 1996. L'analyse de l'eau :eaux naturelles, eaux résiduaires et eau de mer Chimie, physicochimie, interprétation des résultats. 8éme édition. *Dunod, Paris*, 1384p.

Santoir C., Bopda A. 1995. Atlas régional Sud Cameroun. *Office de la recherche scientifique et technique outre mer*, 53p.

Sime-Ngando., T Hartmann H.J., Grolière C.A.1990. Rapid qualification of planktonic ciliates: comparison of improved live counting with other methods. *Applied Environmental Microbiology*, 56: 2234-2242.

Suchel B. 1987. Les climats du Cameroun. *Thèse Doctorat d'état, Université de Bordeaux*, 186p.

Tabue Y.J.G.,Feumba R.,Wethe J.,Ekodeck G.E.,De Marsily G. 2012. Evaluation of Ground water Suitability for Domestic and Irrigational Purposes: A Case study from Mingoa River Basin, Yaunde, Cameroon. *Journal of Water Protection*, 4, 285-293.

Wilbert N. 1969. Okologische untersuchung aufwuchse,und plankton ciliaten eines eutrophen weihers,*Arch Hydrobiol.(Suppl)*,35: 411-518.

Zébazé Togouet. S. H., Njine. T., Kemka. N., Nola. M., Foto. M., Monkiedje. A., Niyitegeka. D., Sime Ngandot. et Judiaël L. 2005. Variations spatiales et temporelles de la richesse et de l'abondance des Rotifères (Brachiomidae et Trichocercidae) et des Cladocères dans un petit lac artificiel eutrophe situé en zone tropical. *Revue des Sciences de l'Eau* 18 (4): 485-505.

Zébazé Togouet S.H., Njiné T., Kemka N., Nola M., Foto Menbohan S., Niyitegeka D.,

Ngassam P. et Boutin C. 2006. Composition et distribution spatio-temporelle des protozoaires ciliés dans un petit lac hypereutrophe du Cameroun (Afrique centrale). *Journal of Water Science*, 19(3): 151-162

