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Influence of physicochemical parameters on zooplankton assemblage in Lake Ossa at Dizangue (Cameroon, Central Africa)

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Abstract

With the increase in anthropogenic activities, monitoring the response of hydro systems to variations in environmental parameters is an imperative for optimal management. Zooplankton is a reliable indicator of these variations, hence their study in Lake Ossa, a UNESCO protected heritage. This research aims to evaluate the influence of physicochemical parameters on the distribution of the zooplankton community in the Lake Ossa from October 2010 to October 2011. Physicochemical parameters were measured in three stations, on the water surface according to APHA and Rodier standards. Zooplanktons were collected from three levels of depth by passing thirty liters of water through a sieve of 64 microns' mesh. The Organic Pollution Index (OPI) has been calculated and the relationships between environmental variables and the distribution and dynamic of the zooplankton community performed by the Principal Component Analysis (PCA), based on the data matrix of zooplankton abundances. The recorded values of parameters expressing the degree of physicochemical pollution of the waters were 16.64±2.41 FTU, 8.70±1.68 mg.L^{-1} and 101.35±11.86 Pt.Co in the rainy season, 22.25±1.96 FTU, 12.25±3.08 mg.L^{-1} and 105.75±13.51 Pt.Co in the dry season. The OPI gives a value of 3.00 which marks the limit between the classes of moderate and strong organic pollution. The results of the PCA show that the Lake Ossa is subject to a seasonality effect expressed by warm and better oxygenated water during the dry season, turbid water at the beginning of the rainy season, and strongly mineralized water at the end of the rainy season. In general, in the Lake Ossa, the most important biomasses were mainly those of rotifers (70 %, principally in the dry season) and nauplii larvae (principally in the rainy season).

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Introduction

Zooplankton is considered to be a true bioindicator of changes in the physicochemical characteristics of aquatic environments (Angeli, 1980; Pourriot,Benest *et al.*, 1982; Pinel-alloul *et al.*, 1990; Moss, 1998;Holynska, Reid *et al.* 2003). It is very sensitive to variations in the conditions of its environment because it is intimately linked to its environment in which it actively participates in the purification of water (Nogrady *et al.*, 1995). A major factor to consider in the hydrosystems state change process is the high level of anthropogenic pollution. Indeed, the pollution produced by the industrial and agricultural activities, as well as urban pollution exerts important pressures on aquatic ecosystems, resulting in a deterioration of the water quality on which depends the aquatic organisms (Wang *et al.*, 2012; Morrissey *et al.*, 2013). Agricultural activities for example (establishment of nurseries, use of fertilizers and biocides, etc.) contribute to the discharge of large quantities of pollutants into the environment. It is thus an important factor of chemical pollution in the environment (Godin *et al.*, 1985). Tening *et al.*, (2013) has certified that countless origins of wastewater and solid wastes are directly discharged in nature without any preliminary treatment. The lake Ossa at Dizangue is one of the three main lakes of the Ossa complex, which is one of the protected wildlife reserves in Cameroon and is classified as a "World Heritage site" by UNESCO. Its banks are occupied by the plantation of oil palms and rubber of SAFACAM, which makes this water body an environment exposed to a fast and important pollution which in the long term will cause its disappearance. It is then imperative, for any policy of durable, rational use and conservation of that ecosystem, to evaluate the health status of the lake and to characterize its zooplankton population in order to appreciate the consequence of the anthropogenic activity on its basin and to establish a relevant protocol of protection.

In Cameroon in general, very few studies were devoted to the weakening of biodiversity as response to the dwindling of the aquatic media (Lévèque and Paugy, 1999; N'Zi *et al.*, 2008; Camara *et al.*, 2009). Despite the importance of the Ossa lake complex and its vulnerability to pollution, very few studies have been conducted on its waters to determine its trophic status, its evolution in time and the structure of living communities, as well as to understand its operation.

The works so far known are those of Nguetsop (1997) and Nziéleu Tchapgnouo *et al.* (2012). Some new works are thoses of Nziéleu Tchapgnouo *et al.* (2016) and Nziéleu Tchapgnouo (2016). Likewise, there is a paucity of information on the structure and the distribution of the zooplankton communities in the complex. Spatial and temporal scales of environmental impacts variation set up a precise frame to evaluate the integrity of an ecosystem (Schuwirth and Reichert, 2012; Borics *et al.*, 2013).

This study then aims to evaluate the impact of the water quality on the diversity and distribution of the zooplankton community in the Lake Ossa.

Materials and methods

Study area and sampling stations

The Ossa lake complex basin lies between latitude 3°45'42" and 3°53' North and between longitude 9°9' and 10°4'12" East (Wirrman and Elouga, 1998). The relief is dominated by flat tops of 80 meters' altitude, but the slopes and lake depressions are quite strong (Wirrman, 1992). The Ossa Lake (Fig. 1) is one of the three main lakes of the complex. It is located at an altitude of 8 m above sea level and is part of a North-South rectangular orientation of about 12 km by 10 km (Wirrman, 1992). The Ossa Lake is situated in the larger of the two basins that formed the complex, the Ossa basin, of 3,103 ha.

The water from this largest watershed transit Lake Mevia, one of the three lakes of the complex. The maximum water depth is 10 meters for an average of 3 meters (Pourchet *et al.*, 1991). The lakes of the complex are fed by rainfall (≈2.9 m/year - data of the SAFACam station and those of the city of Dizangue for the period of 1930-1990) and draining of two watersheds that extend respectively over 55 km² and 110 km².

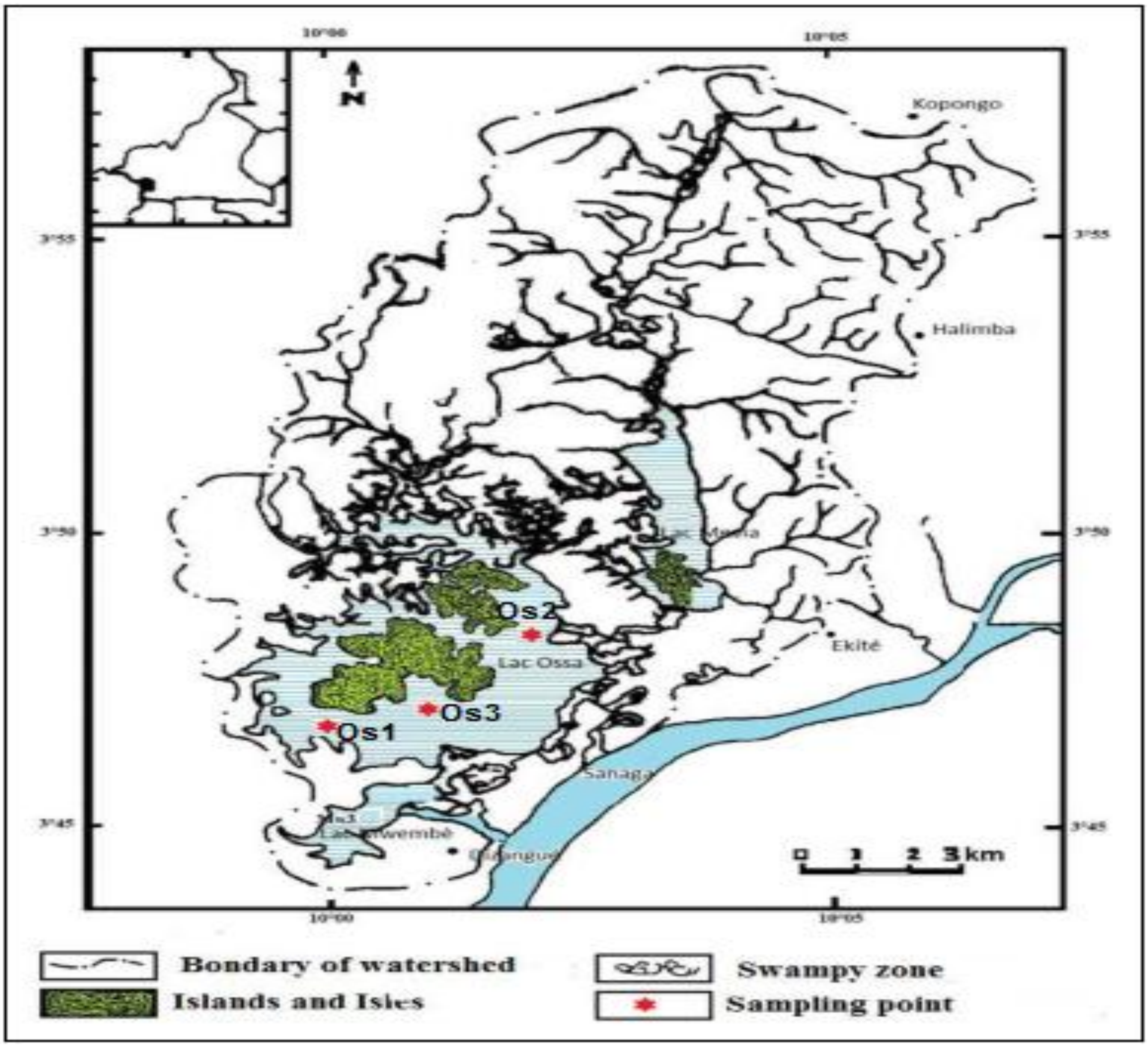

Fig. 1. Geographical location of the Lake Ossa, indicating the sampling stations (National Institute of Cartography, modified by Nziéleu Tchapgnouo).

As for the whole complex, the Ossa lake habours the West African manatee (*Trichecus senegalensis*), the dwarf crocodile (*Osteolaemus monticola*) and many other animals and aquatic and mangrove birds (Wirrman, 1992; MINFOF, 2012). The vegetation around the complex is a swampy forest associated to the industrial palm oil crops and rubber plantation of the (SAFACam) (Wirrman, 1992) which exist since 1897 and covered 95 hectares in 1914 (Wirrman, 1992). This plantation has been extended to 6,800 hectares in 1967, with only 3,850 hectares being exploited as of the 1st of January 1989 (Wirrman, 1992).

The samplings was carried out monthly, from October 2010 to October 2011 in three stations located as follow: the station Ossa 1 (Os_1) is near by the west border of the lake which is occupied by the plantation; Ossa 2 (Os_2) is situated nearly the various small islands of the complex, closely to the lake Mevia, while Ossa 3 (Os_3) is located at the middle of the lake. Sampling period covers both the rainy season (april to october) and the dry season (december to february) and the two months of seasonal transition between the rainy season and the dry season (march and november) Suchel (1988). Water samples were collected between 10 a.m. and 12 a.m using a 03 L bottle of VAN DORN.

Measurement of environmental variables

Samples for physicochemical analysis were collected on the water surface (between 0 and 0.5 m). Five environmental variables (temperature, pH, dissolved oxygen, electrical conductivity and Total Dissolved Solids (TDS)) were measured *in situ*, using a mercury thermometer, a portable pH-meter SCHOTT (CG 818), a portable oxygen meter YSI 52 and a portable TDS/conductivitimeter HACH, respectively, according to the calibration performed at 25 °C in the laboratory before each sampling. In laboratory, measurements of color, suspended solids, forms of nitrogen, orthophosphate, turbidity; Biochemical Oxygen Demand (BOD_5) and dissolved carbon dioxide were done according to APHA (1998) and Rodier *et al.* (2009) standards.

Sampling and identification of zooplankton species

Zooplanktons were collected from three levels of depth: on the surface (between 0 and 0.5 m), above the area of disappearance of Secchi disc and 50 cm above the bottom. Thirty liters of water were collected at the level of each depth and passed through a sieve of 64 microns mesh. One hundred and fifty mL aliquot water was fixed in formalin 4% and another 150 mL were directly brought back to the laboratory. The samples permitted to identify and count zooplankton species. The listing of organisms present within each sample was made on the basis of counting two or three samples of 10 mL (Pourchet *et al.*, 1991). The species of rotifers, Cladocerans and copepod were identified by means of a stereoscopic microscope WILD M5, using the identification keys of Ruttner-Kolisko, 1974; Koste, 1978; Pourriot et Francez, 1986; Nogrady *et al.*, 1993; Nogrady *et al.*, 1995; Segers, 1994; Segers, 1995; Shiel, 1995; Wallace and Snell, 2001) for Rotifers, Kutikova (2002), Amoros (1984), Korovchinsky (1992), Smirnov and Korovchinsky (1995), Smirnov (1996), Dodson and Frey (2001) for Cladocerans and Korinek (2002), Lindberg (1957), Dussart (1980), Van de Velde (1984), Dussart and Defaye (1995) for Copepods.

Data analyses

The Shannon and Weaver index was used to account for the diversity of species that make up the stand in the lake. It establishes the link between the number of species and the number of individuals in the same ecosystem or in the same community. The Pielou index was used to measure equidistribution of stand species with respect to an equal theoretical distribution for all species. It ranges from 0 (dominance of a single species) to 1 (equidistribution of individuals in the stand). These clues were used to evaluate the specific diversity in the lake.

To assess the organic pollution, Organic Pollution Index (OPI) of Leclercq and Vandevenne (1987) (Table 1) has been calculated using the organic parameters (BOD_5, PO_4^{3-}, NH_4^+, NO_2^-) whose classification is done according to five classes (Adour, 2001). Each average value of a parameter corresponds to a class and the index is found by making the ratio of the sum of all the classes of the parameters by the number of parameters.

In order to study relationships between environmental variables and the distribution and dynamic of the zooplankton community, Principal Component Analysis (PCA) was performed based on the data matrix of zooplankton abundances, using R-3.1.1 software. PCA is a constrained ordination method, efficient in directly revealing relationships between the spatial structure of communities and environmental factors that might be responsible for that structure (Legendre *et al.*, 2011).

Results and discussion

Physicochemical quality of water

Values of measured parameters are presented in Table 2. They are the mean values of thirteen measures taken in thirteen months, with standard error.

The average temperature in the entire water body during the rainy season was 29.15±0.48 °C while it was 30.68±0.43 °C in the dry season. The temperature difference between the seasons is certainly related to the division described by Suchel (1987, 1988) and the greater warming of the water in the dry season is justified by the shallowness of the lake which would allow greater penetration of the light to the depth of the water body.

Table 1. Class Limits of the Organic Pollution Index (Leclercq and Vandevenne, 1987).

Classes	BDO_5 (mg/l)	NH_4 (mg/l)	NO_2 (µg/l)	PO^{3-}_4 (µg/l)
5	<2	< 0.1	< 5	< 15
4	2-5	0.1 – 0.9	6-10	16 - 75
3	5.1-10	1 – 2.4	11-50	76 - 250
2	10.1-15	2.5 - 6	51 - 150	251 - 900
1	>15	> 6	> 150	> 900

The temperature range in the lake corresponds to those found in several African lakes (Ramberg, 1987; Okogwu, 2010). As in most tropical lakes, the values of this parameter are relatively stable. The small amplitude in temperature variation is a characteristic of tropical lakes and reveals a relative stability of that parameter (Lewis, 1987).

For the parameters expressing the degree of physical pollution of the waters of Lake Ossa, during the rainy season (turbidity, suspended solids, color), the recorded values were 16.64±2.41 FTU, 8.70±1.68 $mg.L^{-1}$ and 101.35±11.86 Pt.Co while in the dry season they were 22.25±1.96 FTU, 12.25±3.08 $mg.L^{-1}$ and 105.75±13.51 Pt.Co. The values of these parameters are more important in the lake during the dry season, despite the mixing of waters with those from runoff on the watershed and the Sanaga River during the rainy season. The low volume of water during the dry season would justify a higher concentration of particles. In addition, and according to Nguetsop (1997) and Kossoni (2003), manatees that search bottom mud for food would readily release suspended sediments into the water phase. Overall, the low values recorded for these parameters could be explained by the low soil erosion in the watersheds of the Lake Ossa, due to their occupation by the rubber trees and oil palms forests. These values seem to suggest that the waters of the lake are oligotrophic.

Table 2. Values of physicochemical parameters of water samples (RS= Rainy season, DS= dry season).

Parameters (unit)	Min	Max	Mean	RS	DS
Temperature (°C)	27.20	32.00	29.66±0.41	29.15±0.48	30.68±0.43
pH	6.1	8.18	6.61±0.08	6.67±0.11	6.50±0.09
Electric conductivity (µS.cm-1)	16	46	27.86±2.43	29.35±3.12	24.89±3.83
Turbidity (FTU)	7	28	18.51±1.86	16.64±2.41	22.25±1.96
Total Dissolve Solids ($mg.L^{-1}$)	7	22	13.04±1.18	13.72±1.51	11.66±1.90
Color (Pt.Co)	23	151	102.81±8.86	101.35±11.86	105.75±13.51
Suspended solids ($mg.L^{-1}$)	1	19	9.88±1.53	8.70±1.68	12.25±3.08
PO_4^{3-} ($mg.L^{-1}$)	0.001	0.92	0.201±0.077	0.259±0.110	0.085±0.034
NO_2^- ($mg.L^{-1}$)	0.001	0.08	0.009±0.0035	0.012±0.005	0.005±0.001
NO_3^- ($mg.L^{-1}$)	0.009	4.5	0.534±0.211	0.381±0.266	0.842±0.335
NH_4^+ ($mg.L^{-1}$)	0.03	0.87	0.249±0.043	0.199±0.037	0.348±0.084
Dissolve oxygen (%)	45.33	155.12	83.80±4.64	64.44±2.69	123.17±5.12
CO_2 ($mg.L^{-1}$)	1.76	23.4	12.58±1.72	14.66±1.01	8.41±4.35
BOD_5 ($mg.L^{-1}$)	20.00	400	54.88±12.03	67.25±16.45	30.16±3.92

The degree of mineralization of the water is evaluated through pH, electrical conductivity and TDS parameters. Annual averages for these parameters in the rainy season were 6.67±0.11, 29.35±3.12 $\mu S.Cm^{-1}$ and 13.72 ±1.51 $mg.L^{-1}$ while in the dry season they were 6.50±0.09, 24.89±3.83 $\mu S.Cm^{-1}$ and 11.66±1.90 $mg.L^{-1}$. The pH of the waters was slightly acidic. This pH value remains in the range of a normal pH of surface waters; it is conducive to the growth of acid tolerant rotifers and marks a threshold below which freshwater fish are slowed in their growth and reproduction (Ramade 2005). For Ramade (2005), the pH of natural waters should not be less than 6 even for aquatic biotopes located on highly acidic rocks, except in case of regular intake of atmospheric sulfuric acid by so-called acidic rains.

Table 3. Monthly values of the Shannon and Weaver, Piélou and species richness indices in Lake Ossa during the study period.

Months	Stations	Shannon and Weaver	Pielou index	Specific richness
Octobre 2010	Ossa 1	4	0.77	40
	Ossa 2	4	0.77	39
	Ossa 3	4	0.77	40
Novembre 2010	Ossa 1	3	0.57	40
	Ossa 2	3	0.57	41
	Ossa 3	3	0.57	41
Decembre 2010	Ossa 1	4	0.77	38
	Ossa 2	4	0.77	39
	Ossa 3	4	0.77	39
January 2011	Ossa 1	3	0.59	35
	Ossa 2	3	0.59	36
	Ossa 3	3	0.59	36
February 2011	Ossa 1	3	0.6	34
	Ossa 2	3	0.6	36
	Ossa 3	3	0.6	35
March 2011	Ossa 1	3	0.58	37
	Ossa 2	3	0.58	37
	Ossa 3	3	0.58	38
April 2011	Ossa 1	4	0.77	39
	Ossa 2	4	0.77	40
	Ossa 3	4	0.77	40
May 2011	Ossa 1	4	0.81	34
	Ossa 2	4	0.81	34
	Ossa 3	4	0.81	34
June 2011	Ossa 1	4	0.77	40
	Ossa 2	4	0.77	40
	Ossa 3	4	0.77	40
July 2011	Ossa 1	4	0.79	37
	Ossa 2	4	0.79	37
	Ossa 3	4	0.79	37
August 2011	Ossa 1	4	0.82	33
	Ossa 2	4	0.82	33
	Ossa 3	4	0.82	33
Septembre 2011	Ossa 1	3	0.63	29
	Ossa 2	4	0.84	30
	Ossa 3	4	0.84	30
Octobre 2011	Ossa 1	3	0.61	34
	Ossa 2	3	0.61	34
	Ossa 3	3	0.61	34

In comparison with the values of this parameter, recorded by Kling in this lake in 1987 (pH = 7), the waters of the lake became acidified; the slight acidity of the waters of Lake Ossa could be attributed not only to the total hydrolysis of the primary minerals of the yellow ferralitic soil from the sedimentary rocks of the Lake Ossa basin, but also to the elimination of most of the bases (Vallerie, 1968, Ségalen, 1978), with the major consequence of the re-solution of toxic metals previously trapped in sediments.

The highest values of electrical conductivity were recorded during the rainy season when the runoff and the Sanaga River waters mix with those of the lake. This would justify a supply of organic matter by the river and the leaching of agricultural land. Indeed, the contribution of wastewater in the aquatic environment increases its ionizable salts content and consequently its conductivity (Zébazé Togouet *et al.*, 2005). In comparison with the values obtained by Kling (1987), 17.8 µS.cm^{-1}, the content of this parameter in the waters has increased, which supposes a progress towards the eutrophication of the waters of the lake.

Seasonal annual averages of the parameters that characterize organic pollution, PO_4^{3-}, NH_4^+, NO_3^- and NO_2^-, were respectively 0.259±0.110 mg.L^{-1}, 0.199±0.037 mg.L^{-1}, 0.381±0.266 mg. L^{-1} and 0.0120±0.0050 mg.L^{-1}during the rainy season, and 0.085±0.034 mg.L^{-1}, 0.348±0.084 mg.L^{-1}, 0.842±0.335 mg.L^{-1} and 0, 0050±0.0010 mg.L^{-1}during the dry season.

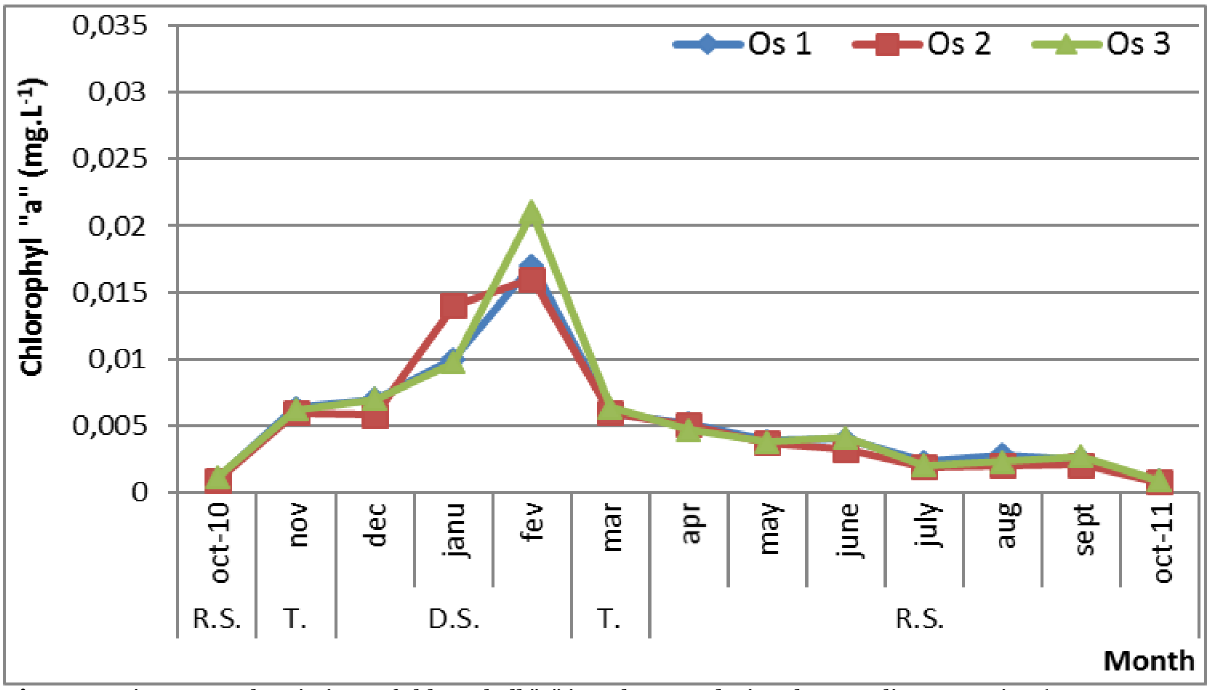

Fig. 2. Spatio-temporal variations of chlorophyll "a" in Lake Ossa during the sampling campaign (Os= Ossa; R.S. = Rainy season; D.S.= Dry season; T= Transition month).

The nutrient water contents PO_4^{3-}, NH_4^+, NO_3^- and NO_2^- are very low when considering the mean values expressed in mg.L^{-1}. These parameters thus reflect globally a poverty of the lake in organic matter. However, Dunnette (1992) estimates that the content of a phosphorus biotope can predict the degree of eutrophication of its waters. Indeed, Ryding and Rast (1994) state that a lentic ecosystem is engaged in an accelerated eutrophication process when the values of PO_4^{3-} and chlorophyll "a" of its waters are respectively greater than 100 µg.L^{-1} and 25µg.L^{-1}, and when it has a Secchi disappearance depth greater than or equal to 1.5 m. The annual average of PO_4^{3-} expressed in µg.L^{-1} in Lake Ossa is 201±77 µg.L^{-1}. That of chlorophyll "a" is 5.7±1.3 µg.L^{-1} in this medium (Fig. 2). Considering the classification by trophic level of the lakes according to their phosphorus content (expressed in µg.L^{-1}) and chlorophyll "a" (expressed in µg.L^{-1}), and the depth of disappearance of the Secchi disc (greater than 1.5 m), it may be suggested that the waters of the lake would at least be involved in an eutrophication process, although the chlorophyll "a" value is less than 25 µg.L-1. Indeed, the OPI gives a value of 3.00 which marks the limit between the classes of moderate and strong organic pollution.

The enrichment of the lake's waters with organic matter is in fact the consequence of the agricultural exploitation of SAFACAM on the watershed, the main anthropogenic activity which, through the use of fertilizers and the production of large quantities of nutrients, brings a significant organic load in the environment, contributing to degrade the quality of its waters.

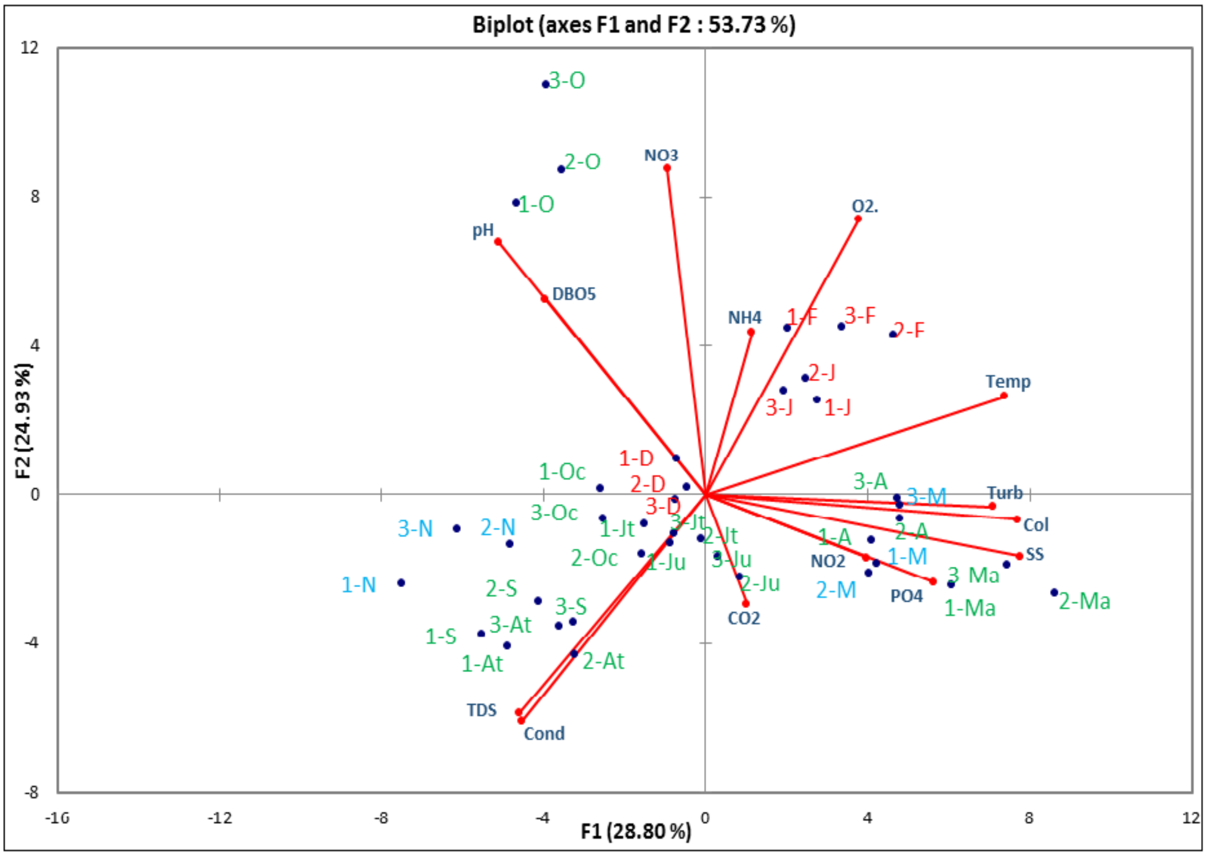

Fig. 3. Principal Component Analysis of the three Lake Ossa stations based on monthly physicochemistry data (O = October 2010, N = November, D = December, J = January, F = February, M = March, A = April, Ma = May, Ju = June, Jl = July, At = August, S = September, Oc = October 2011. 1 = Station 1, 2 = Station 2, 3 = Station 3. Red = dry season, green = rainy season, blue = transition month).

For dissolved gases, during the rainy season, the average oxygen content was 64.44±2.69 % in the whole water body, whereas it reached 123.17±5.12 % in the dry season. The seasonal values of CO_2 were respectively 14.66±1.01 mg.L^{-1} and 8.41±4.35 mg.L^{-1}. The average level of dissolved oxygen in the lake is always greater than 70%. For De Villiers *et al.* (2005) and Ramade (2005), an oxygen level above 70% expresses the existence in the lake of an eutrophication phenomenon which results in intense photosynthetic activity ensured by the plants.

The oxygen gradient in the water is similar to that found in Lake Ehomain Nigeria (Okogwu, 2010) and shows significant seasonal variation; the waters are less oxygenated during the rainy season. Generally, the solubility of oxygen decreases as the temperature increases. But this principle takes into account the activity of aerobic bacteria which increases with temperature thanks to the presence of fermentescible organic matter (FOM). However, the rate of oxygen in the waters decreases during the rainy season. This situation could be attributed to a higher concentration of FOM in this season due to the mixing with Sanaga waters and inputs from watershed runoff, concentration that would cause a rapid consumption of dissolved oxygen by bacteria, hence its decrease. As for the values of dissolved CO_2, they evolve in the opposite direction to those of dissolved oxygen. The increase in the water content of CO_2 during the rainy season has already been observed in Yaounde Municipal Lake and in the ponds of Melen and Éfoulan in Yaounde (Nziéleu Tchapgnouo, 2006).

PCA based on physicochemical data

The results of the PCA on physicochemical data (Fig. 3) show that the variables are distributed along two main axes that together account for 53.73% of the distribution in the lake.

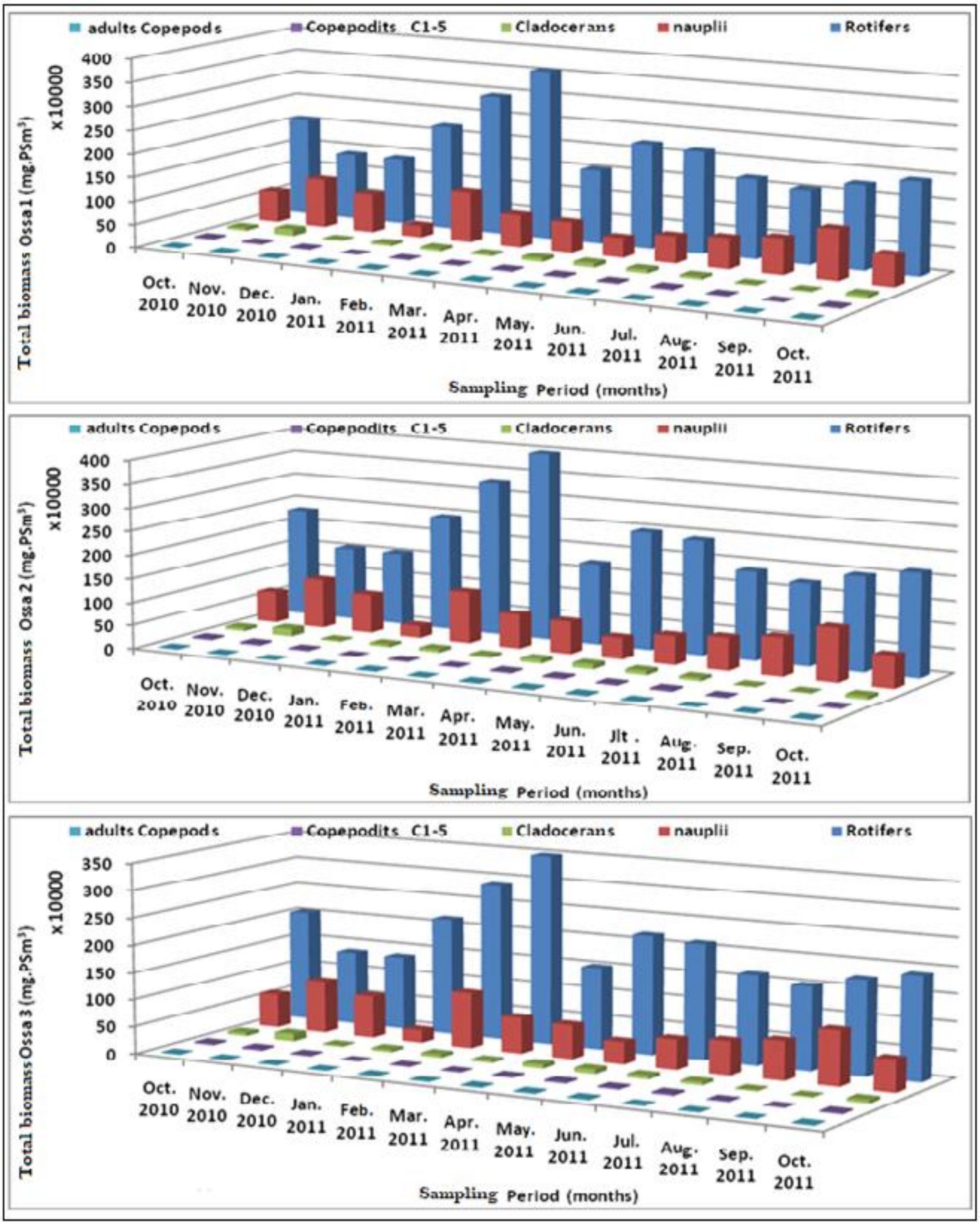

Fig. 4. Total zooplankton biomass at Os_1, Os_2, Os_3 stations of Lake Ossa during the sampling campaign.

The first axis of the PCA accounts for 28.80% of the distribution and puts the group of pH, BOD_5, NO_3^- parameters in opposition to the group consisting of CO_2, NO_2^-, PO_4^{3-}, and to some extent to the group of SS and color, on the one hand, and on the other hand the NH_4^+, oxygen, temperature versus TDS and electrical conductivity parameters; beyond this observation, this axis is that of the seasonal distribution of parameters because highlights the dry season and rainy season months. The second axis contributes 24.93% and expresses an opposition between the mineralization and the ionization of water on the one hand and all forms of pollution on the other hand; it is the water quality axis that also shows the behavior of water at the beginning (April and May) and at the end (September and October) of the rainy season. Lake Ossa is subject to a seasonality effect expressed by warm, better oxygenated water rich in nitrogen compounds during the dry season (December to February), turbid waters rich in SS, PO_4^{3-} and with high value of color at the beginning of the rainy season (April and May), in relation to soil leaching and entrainment of pollutants in the lake, and strongly mineralized water at the end of the rainy season (September and October), translating industrial pollution (N'diaye *et al.*, 2010); The SAFACAM factory would take advantage of the season to release large amounts of pollutants into the lake.

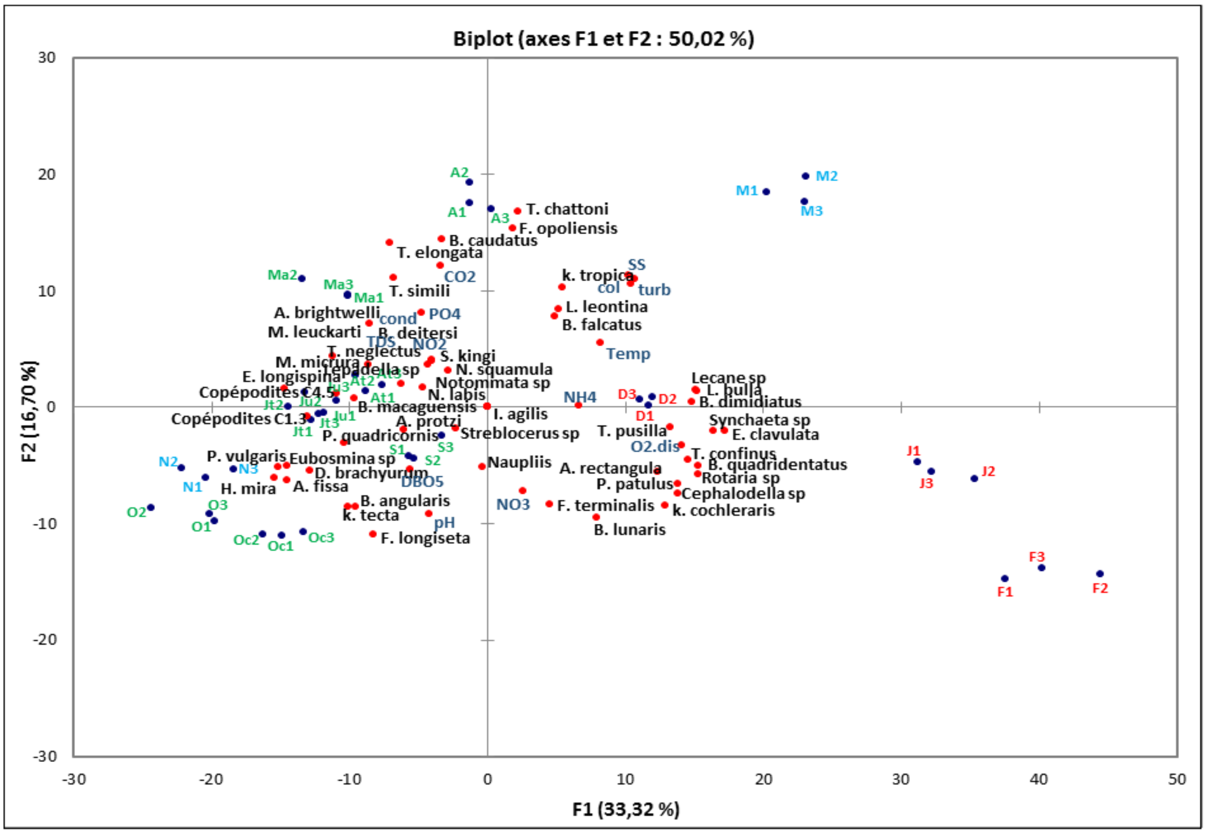

Fig. 5. Structure of zooplankton in Lake Ossa during the sampling campaign.

Biological aspect of water

Chlorophyll "a": At Lake Ossa, the minimum chlorophyll "a" values were all recorded in October and the maximum values in February 2011 (Fig. 2). The mean annual content of chlorophyll "a" in Lake Ossa was 0.0057±0.0013 mg.L^{-1}.Its average value in the rainy season was 0.0033±0.0005 mg.L^{-1}. In the dry season, it was 0.3648 ± 0.0028 mg.L^{-1}.

Indices of diversity and equitability: The Shannon and Weaver index values range from 3 to 4 (Table 3). The value 3 is obtained in the dry season, between January and March 2011, but also in October 2011. The values of Pielou's equitability index varied between 0.57 (November 2010) and 0.84 (September 2011). Only the months of January, March and November have values below 0.60 for this index.

The Shannon and Weaver index values (1949) vary between 3 and 4 and express a relative equitability in the distribution of species in the lake irrespective of the station, although the Pielou index indicates densities a little higher of some species, without significant dominance over others in November, January and March (Piélou index<0.60). For high values of species richness in the lake, Margalef (1958, 1961), Odum *et al.* (1960) and Sevrin-Ryessac (1998) have established a relation between the specific diversity and the degree of stability of a community. For these authors, significant species diversity generally reflects high population stability, as variations of a specie have little influence on the population. However, a lake reaches a state of equilibrium in its species richness and zooplankton population abundance before starting the downward phase of its evolution because then, conditions becoming difficult, only specialized species are maintained and developped. Lake Ossa would indeed have reached the peak of its evolution and would begin the phases of its decline.

Zooplankton biomass: In general, at the three stations of Lake Ossa, the most important biomasses were mainly those of rotifers and nauplii larvae (Fig. 4). In the rotifer group, there is a decrease in biomass between October 2010 and December 2010 before an increase during the dry season, between January 2011 and March 2011. The rotifer biomass then gradually decreased until August 2011.It increases again in September 2011 and October 2011. In nauplii larvae, biomass decreases overall between October 2010 and January 2011. After a significant increase in February 2011, there is a further decrease until May 2011, then a gradual increase until September 2011.

At the Os_1 station, the average rotifer biomass was 1786956±50769 mg.PSm^3 in the rainy season and 2 523857±75393 mg.PSm^3 in the dry season. That of the nauplii larvae was 722 506±5784 mg.PSm^3 in the rainy season and 699844±6043 mg.PSm^3 in the dry season.

At station Os_2, the average rotifer biomass was 1 994 105±59433 mg.PSm^3 in the rainy season against 2 807 474±73376 mg.PSm^3 in the dry season while that of nauplii larvae was 748 902±5791 mg.PSm^3 in the rainy season and 725 412±5745 mg.PSm^3 in the dry season.

At Os_3, average biomass values in rotifers were 1753037±48872 mg.PSm^3 in the rainy season and 2 471799±65982 mg.PSm^3 in the dry season. The biomass of the nauplii larvae was 682198±5991 mg.PSm^3 in the rainy season and 660801±5889 mg.PSm^3 in the dry season.

In general, rotifers contribute more than 70% to zooplankton biomass, unlike temperate zone results where copepods almost always represent more than 60% of zooplankton biomass. (Moison, 2009). The density, and hence the biomass, of the copepods have considerably decreased, confirming the observations of Zébazé Togouet *et al.* (2005) in the tropics. The dominance of rotifers is characteristic of tropical lakes (Bidwell & Clarke 1977, Egborge 1981, Mwebaza-Nadwula *et al.*, 2005, Okogwu 2010, Zébazé Togouet 2011).

The rotiferous biomass is more important in the dry season while that of the nauplii larvae is in the rainy season. As nutrient and phytoplankton biomass levels increase, rotifers, because of their short lifespan and rapid parthenogenetic development, have favored growth (Jalal *et al.*, 2005). The density of rotifers is therefore dependent on the trophic state of the ecosystem. In fact, the quantities of chlorophyll "a" and nutrients (nitrogen and phosphorus) increase in the waters between December and February, favoring primary production and boosting the multiplication of rotifers.

Structure of zooplankton in Lake Ossa

The structure of the zooplankton stand in Lake Ossa is subject, like the physicochemical quality of the waters, to an obvious seasonality with regard to the results of the PCA of Fig. 5 which explains 50.02% of the distribution, and in particular of axis 2 which highlights the rainy and dry season. It can be observed that the months of December to February, characterized by warm waters, highly oxygenated and expressing an organic pollution have the high abundance of species *Lecane* sp., *L. bulla*, *Synchaeta* sp., *B. dimidiatus*, *B. quadridentatus*, *B. dimidiatus*, *B. lunaris*, *K. cochlearis*, *E. clavulata*, *A. rectangula* among others; the common occurrence of several species of brachionidae and lecanidae expresses eutrophic waters (Pourriot, 1968; Sladecek, 1983). Contrary to the results of Lebon (1997), which found abundant lecanidae in waters with high electrical conductivity and NO_2^-, this family in Lake Ossa is negatively correlated with these two parameters, as well as brachionidae with BOD_5, this last family being however defined by Sladecek (1983) as preferring oxygenated media and in which the degradation of organic matter is accentuated.

The abundance of *T. elongata*, *B. caudatus*, *T. simili*, *T. chattoni*, *F. opoliensis*, *A. brightwelli* and *B. deitersi* species is observed in April and May, whereas lake is characterized by trophic pollution and strong mineralization. It is during this period that the abundance of cladocerans is noted, as well as that of copepods *M. leuckarti* and *T. neglectus*. The presence of copepods in this seasonal period contrasts with Moison's conclusions (2009) that during the rise in temperature that favors the algal bloom (phytoplankton ormicrophyto-benthos), the copepods reach a high density; but when the temperature is at its peak, predators grow and competition around food sets in; resources are dwindling, the density curve of copepods is regressing and corrected during the seasonal transition period. Therefore, in the context of this study, we would have expected to observe high densities and a peak abundance inducing a large biomass of copepods between January and March before a decrease in April, which is not the case. In fact, the increase in crustacean biomass is observed between april and May, while that of the nauplii larvae falls. The nauplii biomass, which increased in february, declines as early as march and continues through may. The environmental conditions during this period are favorable for the passage of larvae to the adult stage. This may be due to the absence of predators if we consider, with Moison (2009), that the disappearance of these is favored by the drop in water temperature observed in March.

Waters characterized by high levels of putrescible organic matter, measurable through BOD_5 from August to November, are preferred by species such as *A. protzi*, *D. brachyurum*, *B. macaguensis*, *B. angularis*, *Eubosmina* sp. and the various copepodite stages. With the decrease of the oxygen level in the water, observable through the high values of BOD_5 and NO_3^-, we see the appearance of certain other species of rotifers, and in particular *H. mira*, *K. tecta*, *P. vulgaris*, *F. longiseta*.

Overall, the specific succession in the waters of Lake Ossa is marked by rotifers, including several brachionidae and lecanidae, in the dry season (December to March) while the waters are hot and turbid; between April and August, when the waters are mineralized and marked by trophic pollution, crustacean densities increase then decrease to give place to other species of rotifers that are fond of environments rich in putrescible organic matter (September to November).

Conclusion

The waters of Lake Ossa are well subject to the action of pollution. This is mainly due to the organic matter whose main source is the plantation of SAFACAM. The quality of the water is subject to a seasonality that highlights warm waters rich in nitrogen compounds in the dry season, water subjected to particulate pollution at the beginning of the rainy season (March) and mineralized at the end of the rainy season. The distribution of organisms also follows a seasonal gradient with rotifers present at all times in the water, and cladocerans and copepods, with high abundance in the middle of the rainy season in relation to trophic pollution. Some important ramarques of this study are the confirmation of the dominance of rotifers in tropical waters, the preference of mineralized waters by trichocercidae, but also the reality of pressure of SAFACAM on the degradation of the environment, yet classified as a protected site and the need to reconsider the structure and distribution of zooplankton species in tropical environments.

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References

Amoros C. 1984. Crustacés cladocères. Introduction pratique à la systématique des organismes des eaux continentales françaises. Bulletin Mensuel de la Société Linnéenne de Lyon **3-4,** p 63.

Angeli N. 1980. Interactions entre qualité des eaux et les éléments de son plancton. In: Pesson, Ed. La pollution des eaux continentales. Incidences sur les biocénoses aquatiques. Paris: Gauthier-Villars, 97-146.

APHA. 1998. Standard method for examination of water and wastewater. American Public Health Association, 20th edition, Washington DC, 1150 p.

Bidwell A, Clarke N. 1977. The invertebrate fauna of lake Kainji, Nigeria. Nigerian Field **42(3),** 104-110.

Borics G, Varbiro G, Padisak J. 2013. Disturbance and stress: different meanings in ecological dynamics? Hydrobiologia **711,** 1–7. https://doi.org/10.1007/s10750-013-1478-9

Camara IA, Konan MK, Diomandé D, Edia EO, Gourène G. 2009. Ecology and diversity of freshwater shrimps in Banco National Park, Côte d'Ivoire (Banco River Basin). Knowledge and Management of Aquatic Ecosystems **393(05),** 1-10. https://doi.org/10.1051/kmae/2009020

De villiers J, Squilbin M, Yourassowsky C. 2005. Qualité physicochimique et chimique des eaux de surface : cadre général, Bruxelle, Institut Bruxelloise pour la gestion de l'environnement/Observatoire des données de l'environnement.

Egborge BM. 1981. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. Revue de Zoologie Africaine **95,** 136-180.

Godin PM, feinberg MH, Ducauze CJ. 1985. Modeling of soil contamination by airborne lead and cadmium around several emission sources. Environmental Pollution **10,** 97-114.

Holyńska M, Reid JW, Ueda H. 2003. Genus *Mesocyclops* Sars, 1914. In: Ueda H, Reid JW, Eds. Copepoda: Cyclopoida. Genera *Mesocyclops and Thermocyclops,* Guides to the identification of the microinvertebrates of the continental waters of the world. Backhuys, Amsterdam, **20,** 12-214.

Jalal W, Pinel-Alloul B, Méthot G. 2005. Suivi à moyen terme des impacts écologiques des feux et des coupes forestières sur la communauté zooplanctonique des lacs de l'écozone boréale. Revue des Sciences de l'Eau **18,** 221-248. https://doi.org/10.7202/705585ar

Kling GW. 1987. Comparative limnology of lakes in Cameroun, West Africa. Ph.D thesis, Department of Zoology, Duke University, 482 p.

Korinek V. 2002. Cladocera. Cladocera. In: Fernando CH, Ed. A guide to tropical freshwater. Leiden, Backhugs Publishers, 69-122.

Korovchinsky NM. 1992. Sididae and Holopediidae (crustacea: Daphnii form). In: Dumont HJ, Ed. Guide to the identification of the microinvertebrate of the continental waters of the world. SPB Academic Publishing **3,** p 82.

Kossoni A. 2003. Processus sédimentaire du Lac Ossa (Dizangué, Sud-Ouest Cameroun) et évolution paléoclimatique holocène. Thèse de Doctorat, Université Perpignan, France.

Koste W. 1978. Rotatoria. Die Rädertiere mitteleuropas begründet von Max Voigt. Gebrüder Borntraeger, Berlin.

Kutikova LA. 2002. Rotifera. In: Fernando CH, Ed. A guide to tropical freshwater zooplankton. Leiden, Backhugs Publishers, 23-68.

Leclercq L, Vandevenne L. 1987. Impact d'un rejet d'eau chargée en sel et d'une pollution organique sur les peuplements de diatomées de la Gander (Grand-Duché de Luxembourg). Cahiers de Biologie Marine **28(2),** 311-318.

Legendre P, Oksanen J, Ter Braak CJF. 2011.

Testing the significance of canonical axes in Redundancy Analysis. Methods in Ecology and Evolution **2,** 269–277. https://doi.org/10.1111/j.2041-210X.2010.00078.x

Lévèque C, Paugy D. 1999. Impact des activités humaines. In: Lévêque C, Paugy D, Ed. Les poissons des eaux continentales africaines: diversité, écologie, utilisation par l'homme, Paris : IRD, 365-383. ISBN 2-7099-1432-8.

Lewis WJ. 1987. Tropical limnology. Annual Review of Ecology and Systematics **18,** p 7.

Margalef R. 1958. Temporal succession and spatial heterogeneity in phytoplankton. In: Buzzato-Traverso AA, Ed. Perspectives in Marine Biology, Berkeley, University of California press, 323-349.

Margalef R. 1961. Algunas applicaciones de la informacion en el campo de biologia y concretamenta a la ecologia y al studio de la evolucion. Scientia **55,** 1-7.

MINFOF. 2012. Stratégie du sous-secteur forêts et faune et plan d'action 2013-2017.

Moison M. 2009. Approche expérimentale et numérique du comportement individuel de *Temora longicornis* (Muller, 1792), copépode calanoide typique de la Manche orientale : réponse aux forçages biotiques et abiotiques. Thèse de Doctorat, Université de Lille 1, France.

Morrissey CA, Boldt A, Mapstone A, Newton J, Ormerod SJ. 2013. Stable isotopes as indicators of wastewater effects on the macroinvertebrates of urban rivers. Hydrobiologia **700,** 231–244.

N'diaye AD, Kankou Mosao, Sarr AD, Lo B. 2010. Essai d'évaluation de la turbidité des effluents de la ville de Nouakchott. Revue Ivoirienne des Sciences et Technologie **16,** 69-81.

N'zi KG, Gooré Bi G, Kouamélan EP, Koné T, N'Douba V, Ollevier F. 2008. Influence des facteurs environnementaux sur la répartition spatiale des crevettes dans un petit bassin ouest africain – rivière Boubo – Côte d'Ivoire. Tropicultura **26(1),** 17–23.

Nguetsop VF. 1997. Évolution des environnements de l'Ouest-Cameroun depuis 6 000 ans, d'après l'étude des diatomées actuelles et fossiles dans le lac Ossa. Implications paléoclimatiques. Thèse de Doctorat, MNHN, Paris, France.

Nogrady T, Pourriot R, Sergers M. 1995. Rotifera. Vol. 3. In: Dumont HJ, Ed. The Notommatidae and the Scaridiidae. Guides to the identification of the microinvertebrates of the continental water of the world. SPB Academic Publishing, **8,** 248 p.

Nziéleu Tchapgnouo JG. 2016. Faune zooplanctonique du Complexe lacustre Ossa (Dizangué) : biodiversité et structure des populations de Rotifères, Cladocères et Copépodes. Thèse de Doctorat Ph.D de Biologie Animale, Université de Yaoundé I, Cameroun, 256 + annexe.

Nziéleu Tchapgnouo JG, Zébazé Togouet SH, Foto Menbohan S, Njiné T, Pinel-Alloul B. 2016. Baseline information on the metallic pollution of sediments of the lakes of the ossa complex, dizangue, Cameroon. British Journal of Applied Science and Technology **14(6),** 1-14. https://creativecommons.org/licences/by/4.0

Nziéleu Tchapgnouo JG, Njiné T, Zébazé Togouet SH, Djutso Segnou SC, Mahamat Tahir T, Safia, Tchakonté S, Pinel-Alloul B. 2012. Diversité spécifique et abondance des communautés de copépodes, cladocères et rotifères des lacs du complexe ossa (Dizangué, Cameroun). Physio-Géo- Géographie Physique et Environnement **6,** 71-93.

Nziéleu Tchapgnouo JG. 2006. Etude du déterminisme du polymorphisme des Rotifères

Brachionidae dans trois plans d'eau de Yaoundé: Lac Municipal, étang de Mélen et étang d'Efoulan. Mémoire de D.E.A. en Hydrobiologie et Environnement, Université de Yaoundé I, Cameroun, 62p + annexes.

Odum EP, Cantlon JE, Kornicker. 1960. An organizational hierarchy postulate for the interpretation on species individual distribution, species entropy, ecosystem evolution and the meaning of species variety index. Ecology **41,** 395-399.

Okogwu OI. 2010. Seasonal variations of species composition and abundance of zooplankton in Ehoma Lake, a floodplain lake in Nigeria. Revista de Biologia Tropical **58 (1),** 171-182. ISSN 0034-7744.

Pinel-Alloul B, Methot G, Verreault G, Vigneault Y. 1990. Zooplankton species associations in Quebec lakes: variation with abiotic factors, including natural and anthropogenic acidification. Canadian Journal of Fisheries and Aquatic Sciences **47,** 110-121.

Pourchet M, Pinglot JF, Giresse P, Ngos S, Maley J, Naah E, Pugno JC. 1991. Programme sur les lacs à risque d'éruption gazeuse au Cameroun et en France. Évolution des risques et des tentatives de prévision des éruptions gazeuses (résultats scientifiques). Rapport d'activité, CNRS, Université Fourier J, Grenoble, p 19.

Pourriot R, Benest D, Champ P, Rougier C. 1982. Influence de quelques facteurs du milieu sur la composition et la dynamique saisonniere du zooplancton de la Loire. Acta Oecolgica General **3,** 353-371.

Pourriot R, Francez AJ. 1986. Rotifères. Introduction pratique à la systématique des organismes des eaux continentales françaises. Bulletin Mensuel de la Société Linnéenne de Lyon, 37 p.

Pourriot R. 1968. Rotifères du lac Tchad. Bulletin I.F.A.N. XXX, 471-496.

Ramade F. 2005. Éléments d'écologie : écologie appliquée, 6ème édition, Dunod, Paris.

Ramberg L. 1987. Phytoplankton succession in the Sanyati basin, Lake Kariba. Hydrobiologia **153,** 193-202.

Rodier J, Legube B, Merlet N. 2009. Analyse de l'eau. 9e édition, Dunod, Paris, p 1579.

Ruttner-Kolisko A. 1974. The vertical distribution of rotifers in small alpine lake with a sharp oxygen depletion (Lunzer observe). Verhandlungen des Internationalen Verein Limnologie **19,** 1286-1294.

Ryding SO, Rast W. 1994. Contrôle de l'eutrophisation des lacs et des reservoirs. In : Masson Ed. Paris, France : Collection des Sciences de l'Environnement nº **9,** p 294.

Schuwirth N, Reichert P. 2012. Prévoir la présence des organismes dans les rivières. Eawag News **72,** 14-17.

Ségalen P. 1978. Les sols et la géomorphologie au Cameroun. Cahier ORSTOM, série pédologique **2,** 137-188.

Segers H. 1994. On four new tropical and subtropical Lecane (Lecanidae, Monogononta, Rotifera), Hydrobiologia **287,** 243-249.

Segers H. 1995. Rotifera vol 2: The Lecanidae (Monogononta). In: Dumont HJ, Ed. Guide to the identification of the microinvertebrate of the continental waters of the world. SPB Academic Publishing, **6,** 1-226.

Sevrin-Reyssac J. 1998. Biotreatment of swine manure by production of aquatic valuable biomasses. Agricolture, Ecosystems and Environment **68,** 177-186.

Shannon CE, Weaver W. 1949. The mathematical theory of communication. Illinois, Urbana University Press.

Shiel RJ. 1995. A guide to identification of rotifers, cladocerans and copepods from Australian Inland water. Cooperative Research Centre for Freshwater Ecology. Identification Guide **3,** 1-144.

Sládecek V. 1983. Rotifers as indicators of water quality. Hydrobiologia **100,** 169-201.

Smirnov NN, Korovchinsky N. 1995. Introduction to the Cladocera ITC, University of Ghent, Belgium. p 157.

Smirnov NN. 1996. Chydoridae. In: Dumont HJ, Ed. Guide to the identification of the microinvertebrate of the continental waters of the world. 11, SPB Academic Publishing, the Haye, p 197.

Suchel B. 1987. La répartition des pluies et des régions pluviométriques au Cameroun. Travaux et documents de géographie tropicale **5,** 1-288.

Suchel B. 1988. Les climats du Cameroun. Thèse de Doctorat d'État, Université De Bourgogne, France, 4 tomes, p 1177.

Tening AS, Chuyong GB, Asongwe GA, Fonge BA, Lifongo LL, Mvondo-Ze AD, Bih Che V, Suh CE. 2013. Contribution of some water bodies and the role of soils in the physicochemical enrichment of the Douala-Edea mangrove ecosystem. African Journal of Environmental Science and Technology **7(5),** 336-349.

Vallerie M. 1968. Carte pédologique du Cameroun Occidental au 1/1 O00 000. Notice explicative No 45, ORSTOM, 70p + 1 carte hors texte.

Van De Velde I. 1984. Introduction of new diagnostic characters in Mesocyclops, with African species as an example. Crustaceana (Supplement), 404-419.

Wallace RL, Snell TW. 2001. Phylum Rotifera. In: Academic Press Ed. Ecology and Classification of North American Fresh Water Invertebrates, New York, **8,** 195-254.

Wang S, Qian X, Wang QH, Xiong W. 2012. Modeling turbidity intrusion processes in flooding season of a canyon-shaped reservoir, South China. Procedia Environmental Sciences **13,** 1327-1337. https://doi.org/10.1016/j.proenv.2012.01.125

Wirrmann D, Elouga M. 1998. Discovery of an Iron Age site in Lake Ossa, Cameroonian littoral Province. Académie des sciences. Elsevier Earth & Planetary Sciences **326,** 383-389.

Wirrmann D. 1992. Le lac Ossa: une monographie préliminaire. Revue de Géographie du Cameroun **11(1),** 27-38.

Zébazé Togouet SH, Njiné T, Kemka N, Nola M, Foto Menbohan S, Monkiedje A, Sime-Ngando T, Jugnia LB. 2005. Variations spatiales et temporelles de la richesse et de l'abondance des rotifères (Brachionidae et Trichocercidae) et des cladocères dans un petit lac artificiel eutrophe situé en zone tropicale. Revue des Sciences de l'Eau **18(4),** 485-505.

Zebazé Togouet SH. 2011. Zooplancton et eutrophisation d'un lac en zone tropicale. Edition Univentair Europenne Publishe, Berlin. Sarrebruck, Printed in USA.