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Spatio-temporal distribution of zooplankton and physico-chemistry in some rivers of the agricultural area of Awae (Centre Region-Cameroon)

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Abstract
In view of conservation of zooplankton in hydro-agricultural environments, a seasonal study was carried out from July 2021 to May 2022, to determine their spatio-temporal distribution in relation to the environmental characteristics of Awae streams (Centre Region-Cameroon). Twelve (12) sampling stations were selected. The water physico-chemical variables were analyse using standard methods, while the zooplankton collected were identified using appropriate references. The physico-chemical results showed that the waters were slightly acidic (6.58±0.02 CU), weakly mineralized (21.89±0.35 µS/cm), moderately oxygenated (58.3±4.48%) and subject to high levels of organic pollution. A total of 70 zooplankton taxa were identified, belonging to 22 families and 44 genera. The Chydoridae family (21 taxa) was the most diverse group. Most of the other taxa were monospecific (Rotifers and Ostracods). *Alonella* sp. was the only omnipresent species, while *Acroperus* sp.1, *Acroperus* sp.2, *Chydorus* sp.2 and *Kurzia* sp. were the only regular species. Despite the low species abundance obtained during the long seasons (dry and rainy), the diversity of species in dry season increased than in rainy season. The results of the correlations between biological and physico-chemical variables showed that temperature, electrical conductivity and organic matter have a strong influence on abundance and taxonomic diversity. This study further confirms the impact of human activities on aquatic environments and their resources.

Key words: Zooplankton, distribution, agricultural zone, Awae, Cameroon

1. Introduction
Among human activities, agriculture is the main concern and challenges of sustainable development in Africa and worldwide. In Cameroon, it is the main economic activity that reduces poverty, provides more than 60% of jobs for the population, and contributes an average of 20% to the national Gross Domestic Product (GDP) (MINADER, 2014) [1]. Among the Sustainable Development Goals (SDGs), agriculture has a prominent place, with hopes for modernisation and intensification so as to ensure food self-sufficiency and a considerable reduction in poverty in rural areas (MINEPAT, 2020) [2]. It therefore requires heavy use of chemical inputs to improve yields. Aquatic environments, particularly rivers located in areas where these substances are used intensively, are particularly vulnerable.
Their biocenotic component includes zooplankton organisms, which are good bioindicators of water quality (Zébazé Togouet, 2000) [3] and are responsible for transferring energy to higher trophic levels (Louchart *et al*., 2023) [4]. They are also involved in the biogeochemical cycle of carbon and nutrients (Abo-Taleb *et al*., 2020) [5] and in combating certain tropical diseases (Gao *et al*., 2019) [6] among others. In order to preserve aquatic environments and strengthen agricultural policies, the aim of this study was to assess the spatio-temporal distribution of zooplankton in relation to the physico-chemical quality of some water bodies in Awae.

2. Materials and Methods
2.1 Study area: Awae is a commune located in the Centre region, Mefou and Afamba Division, about fifty kilometres from Yaounde (Anonyme, 2013) [7], the political capital of Cameroon. The climate is equatorial Guinean, with four seasons.

A long dry season (LDS) from mid-November to mid-March, a short rainy season (SRS) from mid-March to mid-May, a short dry season (SDS) from mid-May to mid-August and a long rainy season (LRS) from mid-August to mid-November (Suchel, 1987) [8]. There are red ferralitic lateritic soils and clay marshy soils near watercourses. Vegetation is strongly influenced by an uneven relief with a humid equatorial forest. Agriculture is characterised by subsistence and cash crops produce. The hydrographic network includes several internal catchments and external springs crossing the council area (Anonyme, 2013) [7]. A total of 12 sampling stations were selected (Fig 1), 5 of which (S1, S2, S3, S11 and S12) were located in areas of low agricultural activity and 7 (S4, S5, S6, S7, S8, S9 and S10) in areas of intensive agricultural activity.

2.2 Sampling and measurement of physicochemical and biological variables: Sampling was done twice a season on a monthly basis. Physico-chemical analysis were carried out both in the field and in the laboratory following the recommendations of Rodier *et al*. (2009) [9]. Dissolved oxygen levels were measured using a HANNA HI 9146 oxymeter, while temperature, pH and electrical conductivity were measured using a LAQUA HORIBA PC 220 multiparameter.

3-Other variables such as nutrients (NO2-, NO3-, NH4+, PO4) were measured using the HACH DR/2010 spectrophotometer. As for the zooplankton, a total volume of 100 L of water was sampling from each station and then filtered through a 64 µm mesh plankton net. A 200 ml retentate was fixed with formaldehyde (5%) for identification and enumeration using a WILD M5 binocular magnifier and an OPTIKA optical microscope based on the keys and works of Shiel (1995) [10], Zebaze Togouet (2000) [3] and Fernando (2002) [11] among others.

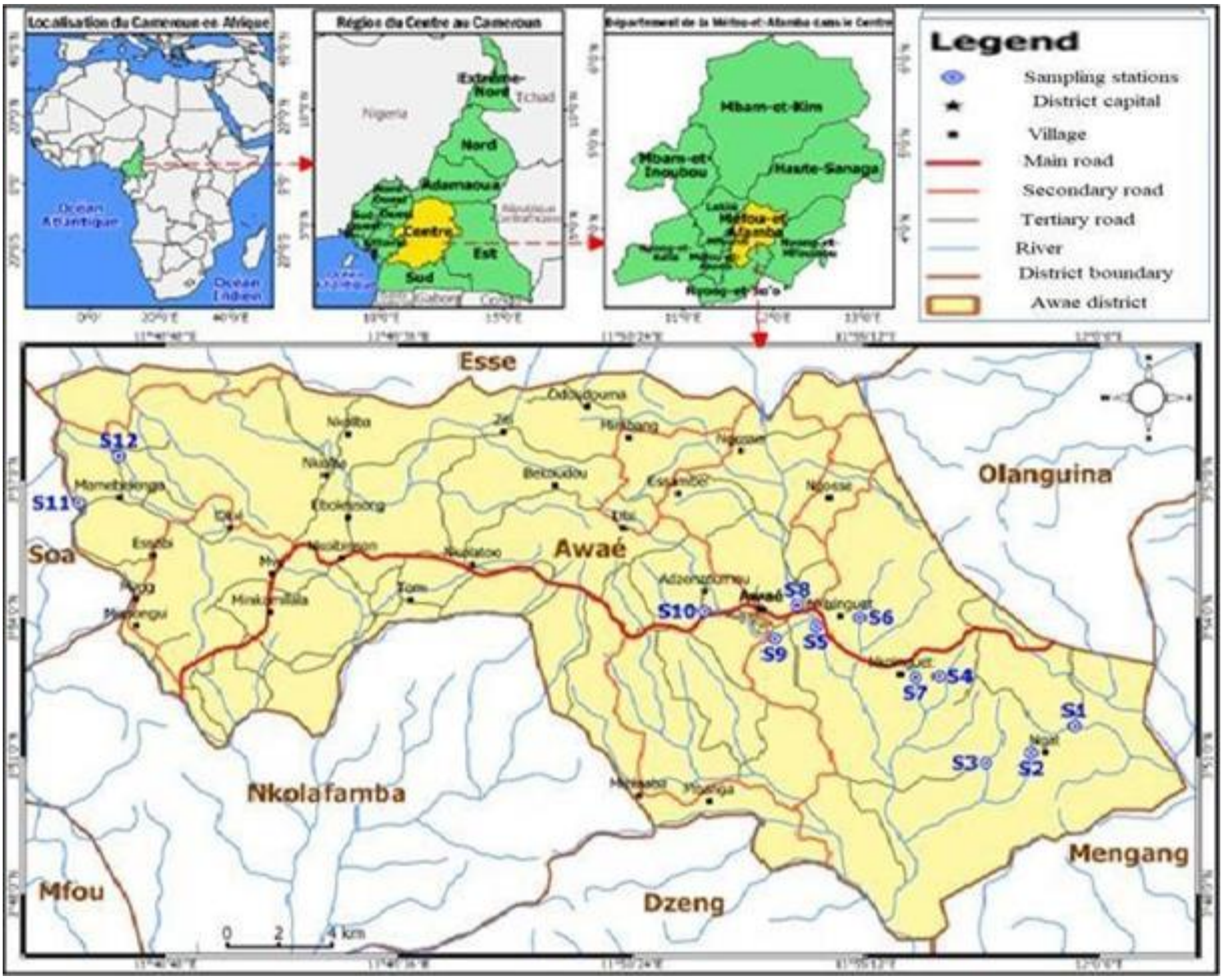

Fig 1: Geographical location of study area and sampling stations in Awae.

2.3 Data analysis

To assess the degree of pollution in each zone, the Organic Pollution Index (IPO) was calculated according to the recommendations of Leclercq (2001) [12]. Kruskall-Wallis and Mann Whitney tests were used to check for significant differences between the values of the variables analysed. Taxonomic abondance was determined and the frequency of occurrence (F) calculated and classified into taxa of five categories: F = 100%: ubiquitous species (*****); 75% ≤ F < 100%: regular species (****); 50% ≤ F < 75%: constant species (***); 25% ≤ F < 50%: accessory species (**); F < 25%: rare species (*). The Shannon-Weaver and Pielou indices were used to determine the structure and dynamics of the zooplankton population. Redundancy Analysis (RDA) and Spearman correlations were used to relate physico-chemical and biological variables. These analyses were carried out using PAST 3.24, Microsoft Excel 2016, SPSS 20.0 and R studio software.

3. Results

3.1 Physico-chemical variables

All the values of the physico-chemical variables were recorded in Table 1 below. The temperature of waters ranged from 20.6 °C, at station S10 in the dry season (LDS) to 25.7 °C, at station S4 in the rainy season (LRS), with an average of 23.2±0.02 °C. The Kruskal-Wallis and Mann-Whitney U tests showed significant differences between stations (p<0.05*) and between seasons (p<0.01**). With regard to suspended solids (SS), the extreme values were noted at station S4 in the dry season and ranged from 0.5 mg/L (SDS) to 36 mg/L (LDS) with an average of 13.4±1.76 mg/L. Significant differences were noted between stations S1 and S6 (p<0.05*) and then between seasons (p<0.01**). pH varied between 5.97 CU (S4) and 7.07 CU (S1) during the rainy season (SRS), with an average of 6.58±0.02 CU. There was a significant difference between stations (p<0.05*) and between seasons (p<0.01**). With regard to water mineralisation, the extreme values for electrical conductivity were recorded in the dry season and ranged from 10 µS/cm at station S3 (SDS) to 48.9 µS/cm at station S11 (LDS), with an average of 21.89±0.35 µS/cm. These variations lead to significant differences between stations (p<0.01**) and seasons (p<0.05*). Dissolved oxygen levels ranged from 23.3% at station S7 (LDS) to 91.6% at station S11 (LRS), with an average of 58.3±4.48%. Significant differences were found between stations (p<0.01*) and seasons (p<0.05*). Dissolved CO_2 levels fluctuated between 0.44 mg/L (S6) and 4.54 mg/L (S1) during the rainy season (SRS), with an average of 2.34±0.28 mg/L. There was no significant difference between the stations (p>0.05*) as opposed to the seasons (p<0.05*). Nitrate levels varied from 0.35 mg/L (S9) to 3.97 mg/L (S12) during the rainy season (SRS), with an average of 1.68±0.2 mg/L. There were significant differences (p<0.05*) between stations and seasons.

Ammoniacal nitrogen levels fluctuated from 0.06 mg/L at station S10 (SDS) to 3.45 mg/L at station S11 (SRS), with an average of 0.78±0.22 mg/L. There was a significant difference (p<0.01**) only between seasons. Orthophosphate levels ranged from 0.14 mg/L at station S9 (LRS) to 3.16 mg/L at station S3 (LDS) with an average of 0.59±0.13 mg/L. There was only one significant difference (p>0.05*) between stations S10 and S11, although there was a significant difference (p<0.01**) between all seasons. With regard to organic matter, the extreme values for oxidability were recorded during the rainy season and ranged from 6.41 mg/L at station S9 (LRS) to 61.61 mg/L at station S6 (SRS), with an average of 24.15±2.21 mg/L. Significant differences (p<0.01**) confirm these variations between stations and between seasons, particularly between SRS and all other seasons. The Organic Pollution Index (OPI) calculated shows values ranging from 2.16 at station S11 (SRS) to 3.5 at station S12 (SDS) with an average of 2.88±0.06. There were significant differences (p<0.05*; p<0.01**) between stations (S1, S2, S9 and S11) and all seasons.

Table 1: Values of physico-chemical variables during the study (Legend: Min = minimum; Max = maximum)

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Temperature (°C)	Min-Max	20,2-24	22-24,5	21,4-24,1	23,5-26	21,5-24,5	21,8-25,7	21,6-25,3	21-25	21-24,3	19,6-24	21,5-24,4	21,5-25,7
	Mean±σ	22,08±0,46	22,78±0,287	22,91±0,37	24,47±0,31	23,61±0,33	23,78±0,48	23,97±0,47	23,25±0,41	22,97±0,35	22,32±0,52	23,01±0,33	23,22±0,44
Suspended solids (mg/L)	Min-Max	2-18	0-28	2-17	0-53	4-43	8-20	0-24	0-21	0-35	0-17	2-52	1-44
	Mean±σ	8,62±1,87	14±3,44	10,12±2,09	15,62±5,92	14,5±4,67	14,87±1,63	12,75±2,82	12,5±2,90	13,37±3,88	10,5±2,25	16,62±5,46	17,37±4,93
pH (UC)	Min-Max	5,84-7,57	5,51-7,08	5,85-6,91	5,19-6,84	6,01-6,82	6,09-6,79	5,53-6,88	5,74-7,07	6,05-6,94	5,61-7,11	6,36-7,11	6,41-7,19
	Mean±σ	6,72±0,18	6,48±0,18	6,57±0,11	6,22±0,21	6,55±0,10	6,61±0,08	6,52±0,16	6,64±0,14	6,58±0,12	6,58±0,15	6,76±0,08	6,77±0,078
Electrical Conductivity (µS/cm)	Min-Max	11-20,7	11-22,2	9-28,9	11-15,27	16-28,8	14-27,5	10-41,2	16-24,3	19 – 31	12-29,6	31-59,2	29-47,1
	Mean±σ	15,60±1,17	15,95±1,10	16,25±2,29	13,51±0,62	22,61±1,44	19,24±1,53	21,52±3,54	20,93±1,02	23,64±1,46	18,18±1,94	40,12±2,93	35,1±2,078
Dissolved Oxygen (%)	Min-Max	35,1-78,5	23,5-78,4	44,3-78,2	36,1-76,1	37,4-87	56,7-93	11,8-74,7	41,7-90,7	7,8-74,8	16,6-56,8	56,4-94,1	21,9-77,4
	Mean±σ	56,88±5,53	44,37±7,51	61,97±4,22	62,86±4,51	64,62±5,67	79,32±4,49	41,31±7,95	66,81±6,49	46,83±8,12	40,55±4,04	80,46±4,54	53,57±6,86
CO_2 (mg/L)	Min-Max	0-5,6	0-3,52	0-3,52	0,6-4,53	0-3,52	0-3,55	1,1-4,6	0-4,9	0,8-7,04	1,23-7,01	0,98-3,52	1,21-4,32
	Mean±σ	2,93±0,68	2,002±0,42	1,98±0,41	2,47±0,50	1,73±0,47	1,59±0,47	2,63±0,44	2,42±0,54	2,72±0,73	3,12±0,71	2,06±0,27	2,42±0,4
NO3 (mg/L)	Min-Max	0,8-4	0 – 2	0-3,6	0,05-4,2	0,05-5	0-3,6	0-5,7	0,03-4,2	0-3	0,01-4,1	1,2-5,2	0,14-6,2
	Mean±σ	1,53±0,37	1,08±0,23	1,43±0,35	1,24±0,46	1,88±0,51	1,78±0,39	2,06±0,67	1,89±0,41	1,33±0,38	1,36±0,44	2,58±0,55	2,03±0,65
NH4 (mg/L)	Min-Max	0,11-0,97	0,25-1,4	0,24-1,78	0-1,27	0,19-1,9	0,15-1,86	0,16-1,26	0,23-3,2	0,08-1,18	0,04-1,86	0,13-6,44	0,1-1,39
	Mean±σ	0,62±0,10	0,61±0,13	0,95±0,19	0,45±0,13	0,63±0,19	0,73±0,19	0,60±0,11	0,94±0,34	0,60±0,12	0,63±0,20	1,87±0,82	0,72±0,19
Phosphates (mg/L)	Min-Max	0,169-1,85	0,04-2,85	0,109-5,94	0,104-2,04	0,136-1,74	0,15-0,704	0,104-3,08	0,07-2,513	0,096-0,61	0,11-2,61	0,218-4,11	0,12-1,69
	Mean±σ	0,49±0,20	0,61±0,32	1,28±0,75	0,52±0,22	0,46±0,18	0,29±0,06	0,92±0,40	0,52±0,28	0,26±0,05	0,46 ±0,30	0,79±0,47	0,49±0,18
Oxydability (mg/L)	Min-Max	11,85-0,23	12,24-45,22	7,3-41,27	5,33-67,54	10,66-61,42	10,27-4,97	11,77-46,21	11,06-52,73	5,33-42,26	12,5-56,68	5,13-53,12	2,96-43,25
	Mean±σ	31,65±5,60	24,52±4,11	21,35±3,52	25,54±8,01	26,11±6,10	30,02±7,61	24,99±4,64	26,15±5,28	18,02±5,15	21,62±5,17	20,31±6,18	19,50±4,7
OPI	Min-Max	2,66-3,33	2,33-3	2,33-3,33	2-3,33	2,33-3,33	2,66-3,33	2,33-3,66	2,33-3,33	2,66-3,66	2,33-3,66	1,33-3	2-3,66
	Mean±σ	2,87±0,08	2,7±0,09	2,75±0,12	2,87±0,18	2,95±0,13	2,87±0,08	3±0,16	2,91±0,16	3,12±0,13	3,04±0,15	2,54±0,2	2,87±0,18

3.2 Biological variables

3.2.1 Variations in taxonomic richness and zooplankton abundance: Taxon abundance varied during the study. Spatially (Fig 2A), it varied between 14 taxa (S6, S9) and 42 taxa (S10). Seasonally (Fig 2B), species abundance was lower during the main seasons. It varied between 41 taxa (LRS) and 50 taxa (SDS and SRS). Despite these variations, no significant differences (p>0.05*) were found in terms of space and time. The patterns of variation in abundance were not entirely consistent with those of species richness. However, spatially (Fig 3A), the low species abundance observed at station S6 resulted in low abundance (26 individuals), whereas the highest abundance (139 individuals) was obtained at station S1. Seasonally (Fig 3B), the highest abundance (222 individuals) found during the rainy season (SRS) also follows its high observed species richness. In contrast to the rainy season, the dry season (LDS) is characterized by low abundance (133 individuals).

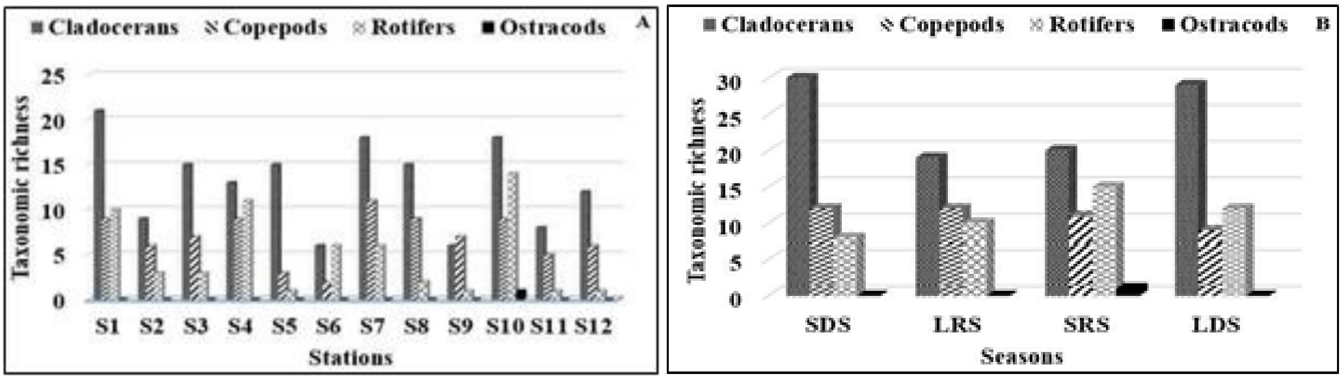

Fig 2: Spatial (A) and seasonal (B) variations in zooplankton taxonomic richness

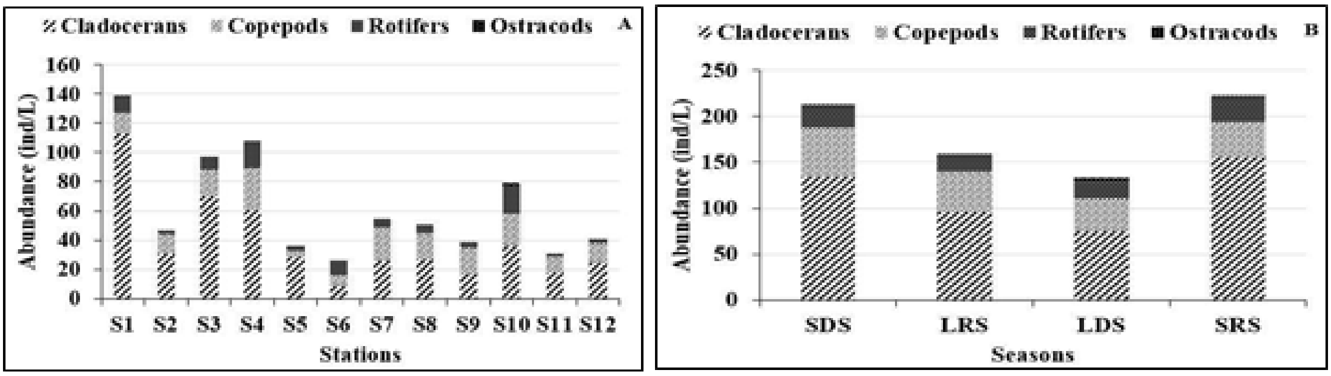

Fig 3: Spatial (A) and seasonal (B) variations in zooplankton abundance during the study period.

3.2.2 Composition of the zooplankton population collected during the study

The population is made up of Cladocerans, Copepods, Rotifers and Ostracods represented by 70 taxa grouped into 22 families and 44 genera (Table 2). The Chydoridae family (21 taxa) was the most diverse, followed by the Cyclopidae (15 taxa). Most of the other families were monospecific (Rotifers and Ostracoda). Among these taxa, *Alonella* sp. was the only omnipresent species, while *Acroperus* sp.1, *Acroperus* sp.2, *Chydorus* sp.2 and *Kurzia* sp. were the only regular species. The constant species are made up of 12 taxa (including nauplius larvae), the accessory species of 32 taxa and the rare species of 22 taxa, mainly represented by Rotifers (Table 3).

Table 2: List and occurrence of zooplankton taxa collected during the study

Groups	Families	Species/Lavae	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Cladocerans	Daphniidae (Strauss, 1820)	*Ceriodaphnia pulchella*	/	/	/	/	**	/	/	/	/	**	/	*
		Ceriodaphnia sp	/	/	/	/	*	/	/	/	/	/	/	*
		Simocephalus sp	/	/	/	/	*	/	/	*	/	/	/	/
		Daphnia sp.	*	/	/	/	**	/	/	*	/	**	/	/
	Moinidae (Goulden, 1968)	*Moinadaphnia* sp.	/	/	/	/	/	/	/	**	/	/	/	*
		Moina micrura	*	/	/	/	**	/	/	**	/	**	/	*
		Moina brachiata	/	/	/	*	*	/	**	**	/	/	/	/
		Moina macropa	/	/	/		*	*		*	/	*	/	/
		Moina sp.	**	/	/	*	/	*	*	*	/	/	/	/
	Sididae (Bairds, 1850)	*Diaphanosoma sarsi*	/	/	/	/	**	/	/	/	/	*	/	/
	Chydoridae (Stebbing, 1902)	*Monope reticulata*	/	/	/	/	/	/	/	**	/	/	/	/
		Pseudochydorus sp.	*	/	/	/	/	/	*	/	/	/	/	/
		Acroperus sp.1	****	***	***	**	/	/	*	/	**	*	/	/
		Acroperus sp.2	****	**	***	**	/	/	*	/	*	*	/	/
		Chydorus sphaericus	***	**	***	/	/	/	*	**	/	/	**	**
		Chydorus haericus	*	**	/	/	/	/	*	/	/	/	/	**
		Chydorus globosus	**	/	/	***	/	/	*	*	**	**	/	*
		Chydorus eurynotus	/	/	/	/	*	/	/	/	/	*	**	/
		Chydorus sp.1	**	/	**	**	*	**	**	**	**	**	/	**
		Chydorus sp.2	****	*	***	***	**	/	*	/	/	*	/	/
		Alona sp.	*	/	*	***	**	/	*	**	/	**	**	**
		Alona cambouei	*	/	/	/	/	/	/	/	***	/	/	/
		Alona rectangular	*	/	**	/	/	/	/	*	/	/	/	/
		Alonella excise	*	/	**	/	/	/	*	/	/	/	**	/
		Alonella sp.	*****	***	***	****	/	/	/	/	/	/	/	/
		Pseudomonospilus sp.	/	/		/	/	/	/	/	/	*	/	/
		Pleuroxus sp.	***	**	***	*	**	**	**	/	/	/	/	/
		Kurzia media	***	*	**	/	/	*	*	*	/	*	*	/
		Kurzia longirostris	**	/	**	*	/	/	/	/	/	/	**	***
		Kurzia sp.	****	***	***	****	/	/	/	/	/	/	/	**
		Camptocercus sp.	*	/	/	/	*	**	*	/	/	*	/	/
	Macrothricidae	*Macrothrix laticornis*	/	/	*	/	/	/	/	/	/	/	/	/

	(Norman et Brady, 1867)	*Macrothrix* sp.	/	/	*	/	/	/	/	/	/	/	/	/
	Ilyocryptidae (Smirnov, 1992)	*Ilyocryptus spinifer*	/	/	/	/	/	/	**	/	/	/	*	/
		Ilyocryptus sp.	/	/	/	/	/	/	**	/	/	/	/	/
		Thermocyclops crassus	/	/	/	/	/	/	/	*	/	/	/	/
Copepods	Cyclopidae (Dana, 1853)	*Thermocyclops oblongatus*	/	/	/	/	/	*/	*	*	/	/	/	/
		Thermocyclops sp.	*	*	/	**	/	/	*	*	**	**	/	*
		Tropocyclops prasinus	*	/	*	**	/	/	**	*	/	*	/	*
		Tropocyclops sp	/	***	/	**	*	/	**	**	**	/	/	/
		Diacyclops sp.	/	*	**	**	*	/	/	*	**	*	/	/
		Mesocyclops sp.	*	*	**	***	/	**	*	**	*	***	**	*
		Cyclops thomasi	*	/	/	*	/	/	*	/	/	/	/	/
		Cyclops bicuspidatus	*	/	/	**	/	/	/	/	/	*	/	*
		Cyclops sp.	**	**	*	***	**	**	**	***	**	**	*	**
		Ectocyclops sp.	/	**	*	/	/	/	**	/	**	*	**	**
		Eucyclops sp.	/	/	/	/	/	/	*	/	**	**	/	/
		Microcyclops sp	/	/	**	/	/	/	/	/	/	/	**	/
		Macrocyclops albidus	*	/	/	/	/	/	/	/	/	/	/	/
		Macrocyclops sp.	*	/	/	**	/	/	**	**	/	**	**	/
		larves nauplius	/	/	**	**	/	/	***	*	/	**	/	**
Rotifers	Brachionidae (Wesenberglun, 1899)	*Platyas quadricornis*	*	/	/	/	**	/	/	/	/	*	/	/
		Platyas sp.	*	*	/	*	/	/	/	/	/	*	/	/
	Philodinidae (Bryce, 1910)	*Macrotrachela plicata*	*	/	***	**	/	**	/	/	/	*	/	/
		Rotaria rotatoria	/	/	/	*	/	/	/	/	/	*	/	/
		Rotaria citrina	**	/	/	**	/	*	*	***	***	***	/	**
		Rotaria sp.	/	*	/	**	/	/	/	/	/	*	/	/
	Trichocercidae (Remane, 1933)	*Trichocerca challoni*	*	/	/	/	/	/	/	/	/	*	/	/
	Mytilinidae (Bartos, 1959)	*Mytilina mucronate*	/	/	/	/	/	/	/	/	/	*	/	/
	Notommatidae (Remane, 1933)	*Cephalodella gibba*	*	/	/	/	/	/	/	/	/	/	/	/
	Trichotriidae (Bartos, 1959)	*Trichotria poecillum*	/	/	/	/	/	/	/	/	/	*	/	/
	Lecanidae (Bartos, 1959)	*Lecane* sp.	**	/	/	/	/	/	/	/	/	*	/	/
	Adinetidae (Bryce, 1910)	*Adineta* sp.	*	/	**	*	/	*	*	/	/	/	/	/
	Euchlanidae (Bartos, 1959)	*Euchlanis dilata*	/	/	/	*	/	/	*	/	/	*	/	/
	Testudinellidae	*Testidunella* sp	*	/	/	*	/	/	/	/	/	*	/	/
	Proalidae (Bartos, 1953)	*Proales* sp.	/	/	/	/	/	*	/	/	/	/	/	/
	Asplanchnidae (Harring et Myers, 1926)	*Asplanchna* sp.	/	/	/	**	/	/	/	**	/	/	/	/
	Collothecidae (Bartos, 1959)	*Collotheca* sp.	/	/	/	/	/	**	*	/	/	/	/	/
		Gastropus sp.	/	/	/	*	/	/	*	/	/	*	/	/
	Gastropodidae (Remane, 1933)	*Ascomorpha* sp.	*	*	**	**	/	**	*	/	/	**	**	/
Ostracods	Darwinulidae	/	/	/	/	/	/	/	/	/	/	*	/	/

Table 3: Spatial and temporal variations of diversity index of Shannon and weaver and Equi index of Pielou

<table>
<tr><td rowspan="5">Stations</td><td></td><td>S1</td><td>S2</td><td>S3</td><td>S4</td><td>S5</td><td>S6</td><td>S7</td><td>S8</td><td>S9</td><td>S10</td><td>S11</td><td>S12</td></tr>
<tr><td>Diversity index of Shannon and Weaver (H’)</td><td>4,3</td><td>3,82</td><td>4,2</td><td>4,5</td><td>4,1</td><td>3,6</td><td>5</td><td>4,6</td><td>3,7</td><td>5,16</td><td>3,7</td><td>4,04</td></tr>
<tr><td>Average H’</td><td colspan="12">4,22 ± 0,4 bits/ind p > 0,05</td></tr>
<tr><td>Equi index of Pielou (J)</td><td>0,7</td><td>0,62</td><td>0,7</td><td>0,7</td><td>0,7</td><td>0,6</td><td>0,8</td><td>0,7</td><td>0,6</td><td>0,84</td><td>0,6</td><td>0,65</td></tr>
<tr><td>Average J</td><td colspan="12">0,68 ± 0,06 p > 0,05</td></tr>
<tr><td rowspan="5">Seasons</td><td></td><td colspan="3">SRS</td><td colspan="3">LRS</td><td colspan="3">LDS</td><td colspan="3">SDS</td></tr>
<tr><td>Diversity index of Shannon and Weaver (H’)</td><td colspan="3">5,03</td><td colspan="3">4,76</td><td colspan="3">5,14</td><td colspan="3">5,12</td></tr>
<tr><td>Average H’</td><td colspan="12">5,01 ± 0,12 bits/ind p > 0,05</td></tr>
<tr><td>Equi index of Pielou (J)</td><td colspan="3">0.82</td><td colspan="3">0.77</td><td colspan="3">0.83</td><td colspan="3">0.83</td></tr>
<tr><td>Average J</td><td colspan="12">0,81 ± 0,02 p > 0,05</td></tr>
</table>

3.3 Influence of some abiotic factors on Zooplankton species

The influence of environmental variables on the abundance of organisms was done by Redundancy Analysis (RDA). The axes F1 = 34.66% and F2 = 20.18% cumulate 54.84% of the total inertia and form two large groups.

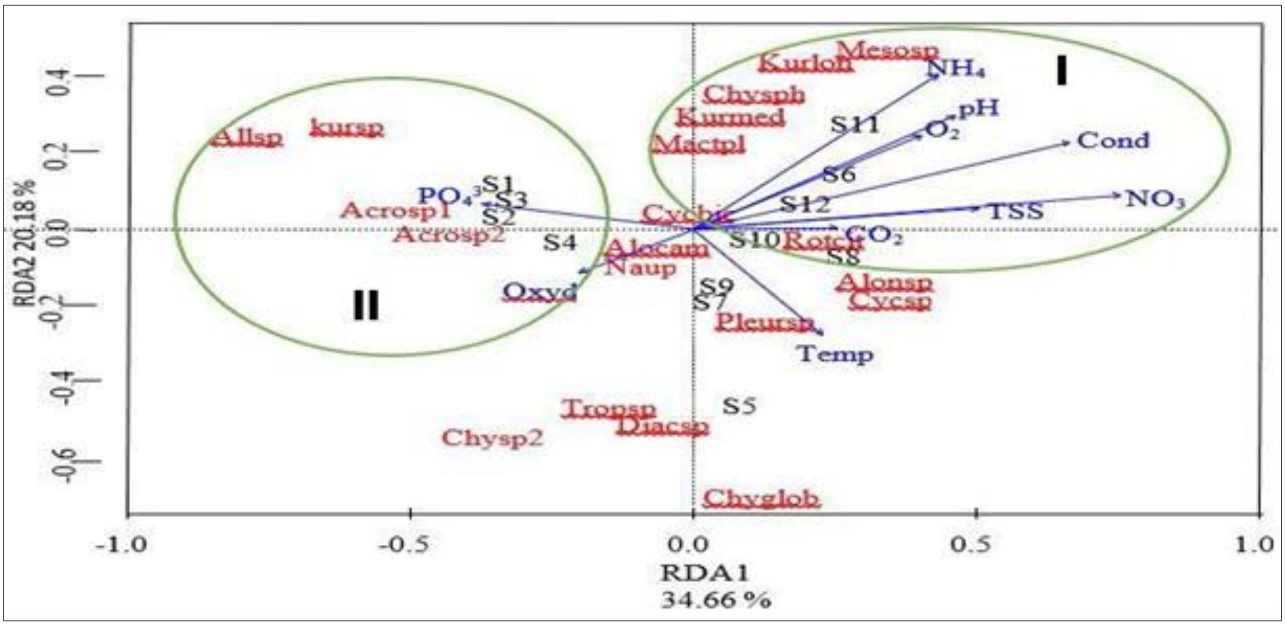

Fig 4: RDA carried out with the numbers of constant, regular and omnipresent zooplankton species and the values of physico-chemical variables.

(Temp: Temperature, SS: Suspended Solids, pH: Hydrogen Potential, Cond: Electricål Conductivity, NO3: Nitrate, NH4: Ammonium, PO4 [3]: Phosphate, O2: Dissolved Oxygen, CO_2: Carbon Dioxide, Oxyd: Oxidability) *Acroperus* sp1: Acrosp1, *Acroperus* sp2: Acrosp2, *Chydorus sphaericus:* Chysph, *Chydorus globosus:* Chyglob, *Chydorus* sp2: Chysp2, *Alona* sp: Alonsp, *Alona cambouei:* Alocam, *Alonella* sp: Allsp, *Pleuroxus* sp: Pleursp, Kurzia media: Kurmed, *Kurzia longirostris:* Kurlon, *Kurzia* sp: kursp, *Tropocyclops* sp: Tropsp, Diacyclops sp: Diacsp, *Mesocyclops* sp: Mesosp, *Cyclops bicuspidatus:* Cycbic, *Cyclops* sp: Cycsp, Nauplius: Naup, *Macrotrachela plicata*: Mactpl, *Rotaria citrina:* Rotcit.

The first group is made up of the species *Mesocyclops* sp, *Kurzia longirostris*, *Kurzia media*, *Chydorus sphaericus* and *Macrotrachela plicata*, which are positively correlated with axis 1, showing that they were well-oxygenated and weak acidic contents of waters. They are negatively correlated with axis 2, showing less warm waters. The second group consists mainly of the species *Acroperus* sp1 and *Acroperus* sp2, which characterise stations S1, S2 and S3, with their tendency for high levels of organic matter, particularly orthophosphate.

4. Discussion

4.1 Physico-chemical characteristic

In this study, the mean temperature of 23.2±0.02°C is higher than 21.98±1.08 °C obtained by Nyamsi Tchatcho (2018) [13]. The variations observed would be linked to the ambient temperature. Bouzidi *et al.* (2010) [14] state that sunshine, the sampling period and the environment affect the temperature of surface waters. The low average TSS value (13.4±1.76 mg/L) can be explained by the presence of abundant plant cover around the stations, which limits soil erosion and water runoff, bringing allogenic matter into the water body (Mbouombouo, 2021) [15]. The average pH of the water was slightly acidic (6.58±0.02 UC) and is close to the 6.69±0.34 UC obtained by Nyamsi Tchatcho (2018) [13] in the same ecological region. This acidity is thought to be due to the acidic nature of the water table in the catchment area. Zebaze Togouet (2000) [3] effectively shows that pH depends on the nature of the crossed landscape. The basic values observed are the result of exogenous inputs, in particular washing activities and the high levels of organic matter used in the catchment areas. The low mineralisation of the water (21.89±0.35 µS/cm) is higher than the 13.16±5.19 µS/cm recorded by Tchakonte (2016) [16] but lower than the 61.94±41.20 µS/cm obtained by Mbouombouo (2021) [15]. These values are very low and far from the values obtained by Foto Menbohan *et al*. (2006) [16] who recorded values in excess of 5000 µS/cm. According to these authors, the increase in mineralisation results from the enrichment of waterbodies by organic matter of anthropogenic origin. Furthermore, the high value obtained in the dry season would indicate the absence of disturbance to the water bodies. The average dissolved oxygen in the water (58.3±0.28%) is close to the 65.57±3.56% recorded by Mbouombouo (2021) [15] and shows that the water is moderately oxygenated. The drop in oxygen levels observed at station S7 was reported by Tchakonte (2016) [17] in the industrial zone with hypoxia ranging from 1.1% to 11.2%. Elias *et al.* (2009) [18] point out that high loads of biodegradable organic matter in a river increase oxygen consumption by decomposing microorganisms. Moreover, the maximum values recorded during the rainy season had already been reported by Tchakonte (2016) [17] and confirm that this season favours rapid water circulation and reoxygenation (Jullian *et al*., 2005) [19]. Average CO_2 levels (2.34±0.28 mg/L) are low, below the 10 mg/L recommended by APHA (1980) [20]. This can be explained by their consumption by photosynthetic plants. Conversely, the high values in some stations may be justified by the respiration of aerobic organisms, which reduce O_2 by increasing CO_2 (MEC, 2003) [21]. As for nitrates, the average content (1.68±0.2 mg/L) is higher than the 0.79±0.59 mg/L obtained by Nyamsi Tchatcho (2018) [13]. The high values at certain stations (S11 and S12) during the rainy season (SRS) are thought to be due to the nitrogenous materials used in agriculture in the catchment areas (Mogue Kamdem, 2021) [22] and transported into the environment during the rains. Average ammoniacal nitrogen levels (0.78±0.22 mg/L) are high compared with the Anonyme (2003) [23]. This is thought to be due to the decomposition of organic matter of non-native origin as well as agricultural activities in the catchment area. The average orthophosphate ion content (0.59±0.13 mg/L) is higher than the 0.18±0.38 mg/L obtained by Nyamsi Tchatcho (2018) [13]. Rodier *et al.* (2009) [9] states that orthophosphate levels above 0.5 mg. L-1 constitute a pollution index. The peak observed in the dry season is thought to be the result of mineralisation of the litter transported during the rains (Nyamsi Tchatcho, 2018) [13] and phosphorus fertiliser inputs (Sommer, 1989) [24] into the catchment. The average oxidability of the water (24.15±2.21 mg/L) is higher than the 4.60±4.56 mg/L obtained by Nyamsi Tchatcho (2018) [13]. This high value reflects the intensification of human activity in the catchment. The high values in the rainy seasons are thought to be due to a synergy of excessive pollution by organic and inorganic matter in the water (Mbouombouo, 2021) [15]. The average OPI (2.88±0.06) shows heavy pollution and is linked not only to the relatively high orthophosphate values but also to diffuse and permanent inputs of agricultural wastewater (Mogue Kamdem, 2021) [22].

4.2 Biological variables

In this study, 70 zooplankton taxa were collected which is higher above the 20 taxa identified by Foto Menbohan *et al.* (2006) [16] and 28 taxa collected by Monney *et al.* (2016) [25]. Unlike some studies in freshwater where Rotifers were the most dominant (Margalef, 1983) [26], Cladocerans were the most diverse and abundant. The increase in the species abundance of cladocerans (30 species) in the dry season (SRS) is thought to be linked to the decrease in temperature and acidity (Okogwu, 2009) [27]. Similarly, their high abundance (156 individuals) in the rainy season (SRS) is thought to be linked to the decrease in temperature, the greater availability of nutrients and the hatching of long-lasting eggs. The dominance of the Chydoridae family has already been reported by Reyl *et al.* (1986) [28], who found a Cladoceran population made up of 90% Chydoridae (18 species) with a high abundance during the rainy season, justifying this dominance by their preference for lotic environments. Copepods are the second most abundant group. Their high abundance at station S9 is thought to be due to the fact that they are better able to escape predation and develop a K-type strategy in environments with limited food resources (Mc Naugit, 1975) [29]. Among Rotifers, the greatest species richness (15 species) is obtained in the dry season (LDS). Okogwu (2009) [27] points out that the increase in species richness in Rotifers generally occurs in the dry season. The low abundance observed during the rainy season (LRS) is thought to reflect the negative influence of the agitation of incoming water, the absence of microhabitats for these organisms, their low relative fecundity (Pourriot *et al.*, 1982) [30] and their greater sensitivity to pollutant discharges (Lair *et al.*, 1998) [31], among other factors. Despite their low abundance, there is a good diversity of Rotifers. Nzieleu (2006) [32] points out that variation in environmental conditions leads to genetic polymorphism and hence to diversity. In the case of ostracods, their virtual absence during the study was due not only to their long development cycle in freshwater (three years) but also to their predation by numerous organisms (Riou, 2021) [33]. This author adds that Ostracods have the ability to proliferate very rapidly when environmental conditions are favourable. Moreover, Ostracod populations in certain environments vary with the seasons, which justifies their presence in the dry season. The high values of the diversity indices are thought to result from the rarefaction of the dominant competitive species (Ayoagui and Bonecker, 2004) [34]. According to Leveque and Balian (2005) [35], the specific diversity of a stand is high when there is no single taxon that is dominant in number, which generally reflects great stability within the stand. Similarly, high Pielou index values indicate a good distribution of species and confirm the homogeneous nature of the environment.

Concerning the influence of physico-chemical variables on zooplankton organisms, the Cladocerans *Chydorus sphaericus* and *Pleuroxus* sp. as well as the Rotifers *Trichocerca challoni* and *Lecane* sp. prefer relatively warm waters (r =-0.80, r =-0.66, r =-0.80 and r =-0.66; p<0.05 respectively). These low temperatures are thought to be responsible for the low abundance of Rotifers, as their reproduction depends on temperature (Mogue Kamdem, 2021) [22]. Many species adapt to the pH values observed. This is the case for *Kurzia longirostris*, which prefers slightly acidic water (r = + 0.63; p<0.05). Furthermore, low mineralisation would have negative impacts on several species including Acroperus sp.1 and *Acroperus* sp.2 (r =-0.87 and r =-0.83 respectively with p<0.01), *Chydorus* sp.2, *Allonella* sp., *Kurzia media*, *Macrothracela plicata* and *Testidunella* sp. (r =-0.67, r =-0.82, r =-0.68, r =-0.62 and r =-0.64 respectively; p<0.05) among others. Similarly, low nitrate levels had a negative impact on the species *Acroperus* sp.1, *Rotaria* sp. (r =-0.76 and r =-0.74; p<0.01 respectively) and *Allonella* sp. (r =-0.65; p<0.05). *Moina* sp. prefers environments rich in organic matter, including dissolved CO_2 and oxidability (r = + 0.61 and r = + 0.65; p<0.05), while *Allonela excisa* prefers phosphate-rich environments (r = + 0.60; p<0.05). These results are in line with those of Mogue Kamdem (2021) [22] who mentioned that an environment rich in nutrients would be favourable to the development of cladocerans. The IPO shows that *Moina macropa*, *Daphnia* sp., *Trichocerca challoni* and *Lecane* sp. develop better in heavily polluted environments (r = + 0.66, r = + 0.68, r = + 0.61 and r = + 0.65 p<0.05). These results confirm the comments of Mogue Kamdem (2021) [22], who emphasised that Lecanidae and Moinidae can be said to be polluotolerant, and that Rotifers are abundant in waters rich in organic matter.

5. Conclusion

This study shows that the waters were slightly acidic with relatively low temperatures, moderately oxygenated, poorly mineralised but with high levels of nutrients, resulting in high levels of organic pollution. The zooplankton community collected was hightly diversed and made up of four major groups, of which the Cladocerans were the most diversed and abundant, and with *Alonella* sp. as the dominant taxon. Their large size explains their adaptation to water currents and their tolerance to pollution compared with other groups. Spatial and temporal variations in zooplankton therefore depend on the hydrological and physico-chemical characteristics of the environment, which are also influenced by human activities.

6. References

1. Minader. Plan de Gestion des Pesticides. Projet d'Investissement Et de Développement des Marches Agricoles (PIDMA); c2014, 12.
2. Minepat (Ministère de l'Économie, de la Planification ET de l'Aménagement du Territoire). Stratégie Nationale de Développement (SND30) 2020-2030. 231.
3. Zébazé Togouet SH. Biodiversité et dynamique des populations zooplanctoniques (ciliés, rotifères, cladocères et copépodes) du Lac Municipal de Yaoundé

(Cameroun). Thèse de Doctorat de troisième cycle, Université de Yaoundé I Cameroun; c2000, 175.
4. Louchart A, Holland M, McQuatters-Gollop A, Artigas LF. Modifications de la diversité du plancton: Bilan de santé. Commission OSPAR, Londres. 2023;7.
5. Abo-Taleb H, Ashour M, El-Shafei A, Alataway A, Maaty MM. Biodiversity of *Calanoida Copepoda* in Different Habitats of the North-Western Red Sea (Hurghada Shelf). Water. 2020;12:656.
6. Gao J, Yang N, Lewis FA, Yau P, Collins III JJ, Sweedler JV, Newmark PA. A rotifer-derived paralytic compound prevents transmission of schistosomiasis to a mammalian host. Biology. 2019;10:17.
7. Anonyme. Plan Communal de Development D'AWAE (PCDA); c2013, 131.
8. Suchel B. Les climats du Cameroun. Université de Bordeaux III. 1987;1863.
9. Rodier J, Legube B, Merlet N, Brunet R, Mialocq JC, Leroy P. Analyse de l'eau (Eds). Dunod, Paris, 9e Edition. 2009;1579.
10. Shiel RJ. A guide to identification of rotifers, cladocerans and copepods from Australian Inland water. CRCFE Identification. 1995;3:144.
11. Fernando CH. A Guide to Tropical Freshwater Zooplankton: Identification, Ecology and Impact on Fisheries. Vol. 290, Backhuys Publishers, Leiden. 2002;50-144.
12. Leclercq L. Intérêt ET limite des méthodes d'estimation de la qualité de l'eau. Station scientifique des Haute-Fagnes, Belgique, Document de travail. 2001;44:26.
13. Nyamsi Tchatcho NL. Macroinvertébrés Benthiques du réseau hydrographique de la Méfou: habitat, diversité et dynamique des peuplements, évaluation de l'intégrité biologique des cours d'eau. Thèse de Doctorat/Ph. D, Université de Yaoundé I, Cameroun; c2018, 251.
14. Bouzidi M, Youcef A, Latrèche A, Benyahia M, Bouguenaya N, Meliani H. Copépodes, Cladocères et Rotifères du lac Sidi Mohamed Benali (Algérie Nord Occidentale). Géographie Physique et Environnement. 2010;4:19.
15. Mbouombouo M. Caractérisation des formes matures de dissémination des Protozoaires et Helminthes intestinaux dans le réseau hydrographique de la Mezam (Région du Nord-Ouest, Cameroun) et influence des variables abiotiques. Thèse de Doctorat/Ph. D, Université de Yaoundé I, Cameroun. 2021;215.
16. Foto Menbohan S, Njine T, Zébazé Togouet SH, Kemka N, Nola M, Monkiedje A, Boutin C. Distribution spatiale du zooplancton dans un réseau hydrographique perturbé en milieu urbain tropical (Cameroun). Bulletin de la Société d'Histoire Naturelle de Toulouse. 2006;142:53-62.
17. Tchakonté S. Diversité et structure des peuplements de macroinvertébrés benthiques des cours d'eau urbains et périurbains de Douala (Cameroun). Thèse de Doctorat/Ph. D, Université de Yaoundé I, Cameroun. 2016;205.
18. Elias R, Rivero MS, Sanchez MA, Jaubet L, Vallarino EA. Do treatments of sewage plants really work? The intertidal mussels' community of the southwestern Atlantic shore (38°S, 57°W) as a case study. Revista de Biologia Marina y Oceanografia. 2009;44:368.
19. Jullian E, Hirbe A, Ker BN, Liu RZ. Qualité de l'eau du bassin versant de l'Ardèche. Université de Paris 7-Denis-Diderot, UFR des Sciences Physiques de la Terre (IUP Génie de l'Environnement); c2005, 149.
20. APHA. Standard methods for examination of water and wastewater. APHA-AWWA-WPCF (Eds.), Pennsylvania, Washington DC. 1980;1150.
21. MEC (Ministère de l'Environnement du Canada). Avis concernant l'aération ou la circulation artificielle de l'eau des lacs comme mesures de restauration de la qualité de l'eau; c2003, 11.
22. Mogue Kamdem GJ. Etude comparée des communautés zooplanctoniques et des niveaux trophiques de quelques étangs à Bertoua (Est-Cameroun). Thèse de Doctorat/ Ph.D, Université de Yaoundé I, Cameroun; c2021, 219.
23. Anonyme. SEQ-Eau (Système d'évaluation de la qualité de l'eau des cours d'eau)-MEDD & Agences de l'eau. Grilles d'évaluation Version 2; c2003.
24. Sommer U. Nutrient status and nutrient competition of phytoplankton in a shallow, hypertrophic lake. Limnol Oceanogr. 1989;34:1162-73.
25. Monney I, Nahoua OI, N'doua ER, N'guessan AM, Bamba M, Tidiani K. Distribution du zooplancton en relation avec les caractéristiques environnementales de quatre rivières côtières du Sud-est de la Côte d'Ivoire. Journal of Applied Biosciences. 2016;82:7326-38.
26. Margalef R. Limnología. Omega, Barcelona; c1983. 1009.
27. Okogwu OI. Seasonal variations of species composition and abundance of zooplankton in Ehoma Lake, a floodplain lake in Nigeria. Revista de Biologia Tropical. 2009;57:171-82.
28. Reyl J, Vasquez E. Cladocères de quelques corps d'eaux du bassin moyen de l'Orénoque (Venezuela). Annales de Limnologie. 1986;22:137-68.
29. Mac Naugit DC. A hypothesis to explain the succession from calanoids to cladocerans during eutrophication. Verh Int Ver Limnol. 1975;19:724-31.
30. Pourriot R, Benest D, Champ P, Rougier C. Influence de quelques facteurs du milieu sur la composition et la dynamique saisonnière du zooplancton de la Loire. Acta Oecol Gener. 1982;3:353-71.
31. Lair N, Reyes-Marchant P, Jacquet V. Développement du phytoplancton, des Ciliés et des Rotifères sur deux sites de la Loire moyenne (France), en période d'étiage. Annales de Limnologie. 1998;34:35-48.
32. Nziéleu Tchapgnouo JG. 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., Université de Yaoundé I, Cameroun. 2006;62.
33. Riou PJ, Noël P, Müller Y. *Ostracodes* spp. Doris; c2021.
34. Ayoagui ASM, Bonecker CC. Rotifers in different environments of the upper Parana River floodplain (Brazil): richness, abundance and the relationship to connectivity. Hydrobiologia. 2004;281-90.
35. Lévêque C, Balian EV. Conservation of freshwater biodiversity: Does the real world meet scientific dreams? Hydrobiologia. 2005;542:25-6.