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Research Article

Biodiversity and Community Structure of Micro-Arthropods in the Memve'ele Dam, the Tributary River and the River Receiving the Evacuated Turbine Water (South-Cameroon)

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Abstract

A survey was undertaken from July 2021 to January 2022 in South-Cameroon on the biodiversity of micro-arthopods in the Memve'ele dam (Site 1), the tributary river (Site 2) and the adjacent river (Sites 3 and 4). Four abiotic parameters were measured *in-situ* while nine other abiotic parameters were measured in the laboratory using standard methods. Micro-arthopods were counted and identified. Water quality was determined. BOD_5, conductivity, NO_2^-, NO_3^-, pH, PO_4^{3-}, temperature and suspended solids were on average within the standards for drinking water. Chlorophyll a, color, DO, NH_4^+ and turbidity values were on average above the standard upper limits. Based on the water quality index (WQI) raw waters were unfit for direct drinking (Dam: WQI=898.864; Site 2: WQI=752.451; Site 3: WQI=883.808; and Site 4: WQI=1,665.883) and presented ideal conditions for fish farming or irrigation for agriculture. A total of 5,487 specimens belonged to three classes, eight orders, 20 families, 57 genera, and 87 species and morphospecies (54 freshwater and 33 tolerant species able to develop in at least two water environments). *Ectocyclops* sp. was the most recorded species (10.6%), followed by *Cyclops* sp. (9.1%), *Alona costata* (8.9%), *Mesocyclops* sp. (7.9%), *Tropocyclops* sp. (7.5%), *Senecella calanoides* (6.8%), *Diaphanosoma sarsi* (6.1%), while other species were represented each by less than 5.0%. Low species richness, high species diversity and a very low dominance by a few species were noted. Assemblages were highly even (Pielou's index close to 1). Species exhibited in all sites, a positive global net association. The assemblage recorded during the wet season at Site 3 functioned as a pioneer community (Broken-Stick model) while, the assemblage recorded during the dry season at Site 2 and the one recorded during the dry season at Site 3 functioned as nomocenosis (log-linear or log-normal models) and were therefore little evolved. In contrast, during the two seasons in the dam and Site 4, as well as during the rainy season in Site 2 and the combined seasons in Site 3, the assemblages functioned as highly evolved communities (Zipf or Zipf-models) with significant regenerative force, suggesting that these assemblages maintained a complex information network developed at spatio-temporal scales. The evolved state (close to natural balance) of the micro-arthopods communities should be preserved and protected.

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Keywords

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1. Introduction

Water quality depends on the kinds and amounts of substances dissolved, and on how they impact the desired use (drinking, household purposes, fish farming, agriculture, recreation, or industrial processes). Parameters include chemicals, physical and biological characteristics, based on the standards of its usage [1]. The sensitivity of the water fauna to the environmental variations can be a potential indicator of the water quality. Several studies have been developed concerning Ostracods as environmental tracers [2], zooplankton diversity in lakes or polluted freshwater ecosystems [3, 4]. In Cameroon available reports concern the importance of the physico-chemical parameters and the zooplankton species diversity in fishponds in Yaoundé [5], the community structure of zooplankton in crater lakes at Barombi Mbo, Mboandong, Lakes Kotto and Soden in West Cameroon [6], the species richness, diversity and distribution of phytoplankton in fertilized ponds of the western highlands agro-ecological zone [7], the diversity and the ecology of the freshwater phytoplankton in Batika river in Yabassi [8], and the spatio-temporal distribution of zooplankton in relation to abiotic factors in the urban hydrosystem in Douala [9]. In short, freshwater is an environment in which groups of macro- and micro-organisms undergo certain stages of their development or their entire life cycle. Freshwater is vulnerable to climate change since many species have limited adaptation abilities as the environment changes. Freshwater fauna is rich and diverse and all kingdoms of life are represented [10]. Several methods exist to access freshwater quality based on the fauna, the most common being the evaluation of micro-arthropods occurrences [11]. Micro-arthropods can occupy marine, brackish, and freshwater and the differences include trophic preferences, reproduction type, and dispersal ability [12]. According to WoRMS database, 110,664 species are aquatic living micro-arthropods [12], but the number is below reality because several forms are still undetermined [12, 13]. Micro-arthropods (marine, brackish and freshwater specialists) are very important for the ocean and freshwater ecology as essential component of the aquatic food web for fish and other macro-invertebrates as well as mocro-vertebrates. They have an economic importance as bio-indicators of the water quality [2]. Memve'ele dam and the tributary river (South Cameroon) are source of drinking water and fishing activities and residents depend on artisanal small-scaled fishing using canoes for household consumption and to supply the neighboring urban areas [14]. Fishermen complain about the scarcity of fish catches [14]. But nothing is known on the community structure of micro-arthropods in the dam. The present study aimed to establish a baseline of information on the diversity and the community structure of micro-arthropods.

2. Material and Methods

2.1. Study Sites

Studies took place from July 2021 to January 2022 at Menve'ele Dam (02°22'24"N, 10°20'59.44"E and 02°22'41.70"N, 10°21'40.14"E) located in the Ntem basin (Southern coastal zone of Cameroon) and the neighboring rivers (Figure 1A). The prevailing climate is tropical with rainfall even during the driest months (December and January: 54.2 mm and 33.8 mm respectively) [15]. The average air temperature ranges from 24.4°C (August) to 26.7°C (Marsh) and the average rain fall ranges from 116 mm (January) to 340 mm (September). The average air humidity ranges from 84.0% (January to March) to 87.0% (September and October) [15]. Four seasons are defined (a long dry season from mid-November to mid-March, a short rainy season from mid-March to mid-June, a short dry season from mid-June to mid-August, and a long rainy season from mid-August to mid-November). Soils are acidic, yellow ferralitic types, poorly rich in minerals and organic matters and soils on gneiss outcrop cover the bulk between Campo and Kribi [16]. Many streams cross the region, the main rivers being Nyong, Lokoundje, Kienke, Lobe and Ntem which flow into the Atlantic Ocean [16]. The watercourses are used by residents for traditional fishing or as waterways using canoes or other navigation fleet [16]. Menve'ele dam is a large artificial lake in Nyabessan village, supplied by the Ntem River which crosses the Nsebito village. Samplings were set up in four sites chosen for their fish farming interest and their position from the Memve'ele dam (Figure 1B). They were accessed using a wooden canoe. Site 1 (in the dam) was located in Nyabessan village (02°22'35.39"N, 10°21'22.55"E) at the water catchments (Figure 1B). Site 2 (02°23'44.91"N, 10°23'51.73"E) was located upstream in Nsebito tributary (6.14 km from the dam) (Figure 1B).

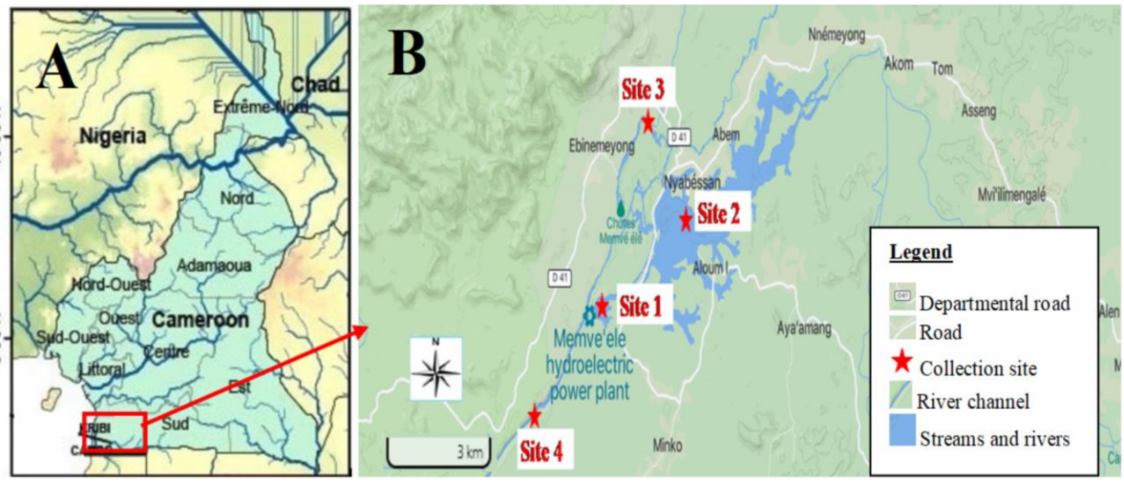

Figure 1. *Location of the study sites in South Cameroon. A: location of the Ntem basin in Cameroon). B: Location of the water collection sites.*

Sites 3 (02°25'12.43"N, 10°22'14.77"E) in Ndjo'o river (4.12 km from the dam and 5.12 km from Site 2) and Site 4 (02°20'47.13"N, 10°19'19.04"E) in Ndjo'o river, was located south of the dam and received turbine waters (Figure 1B). Site 4 was near a tourist area. A Garmin GPS was used for coordinate's registration.

2.2. Sampling Design

Four sampling sessions were done at each site (one in September, October, December and January respectively). For the collection of zooplankton, the water was collected from the surface, at the lentic facies level and after stirring the herbarium, using a 10 litters bucket and filtered using a plankton sieve (opening diameter: 40 cm; mesh size: 64 µm). The process was repeated six times to achieve 60 litters of filtered water. The net was then rinsed with sample water in the opposite direction to that of filtration, avoiding the recovery of plants and solid debris, and the rinsing water was introduced into labelled 100 ml glass vial was fixed using 5% formalin. Collected waters were stored in a Coleman cooler containing pieces of ice for temperature maintenance.

2.2.1. Physico-Chemical Parameters

For the physicochemical parameters of the water, four parameters (DO, electrical conductivity, pH, and water temperature) were measured *in situ* between 8 a.m. and 11 a.m.. In the laboratory, BOD_5, SS, water color, turbidity, NH_4^+, NO_2^-, NO_3^-, and PO_4^{3-} and were measured using a HACH DR/3900 spectrophotometer. The water temperature was measured at each collection site using a mercury column thermometer graduated at 1/10 ℃. The pH and conductivity measurements were made using a portable electronic multi-parameter device (Water-Proof brand). The water turbidity (in FTU) and color (in Pt-Co) were measured on 10 ml raw water using the Wagtech 7100 brand photometer. DO (in $mg.l^{-1}$) was measured by the direct method using the EuTech brand oximeter model CSDO 110 calibrated has been recorded. BOD_5 (in $mg.l^{-1}$) was measured by the respirometryic method by incubating 157 ml of sample water at 20 ℃ in a Carlberg brand BOD incubator. The nitrates and nitrites in 10 ml of raw water was measured using the Nitracol III reagent at 507 nm wavelength for nitrates, the Nitracol III and IV reagents at 565 nm wavelength for nitrites. The water quality index (WQI) was calculated using the Horton's method [29] and the unit weight was determined using WHO's standards [17]: WQI= (sum of q_iw_i)/(sum of w_i) with q_i as the quality rating of i^{th} parameter, w_i as the unit weight of i^{th} parameter. The quality rate $q_i=100(v_i-v_{id})/(s_i-v_{id})$ was determined with v_i as the record in the i^{th} sample for the water quality parameter, v_{id} represented the ideal value of i^{th} parameter in the pure water (v_{id} for pH is 7 and 0 for other parameters), and s_i was the maximum WHO's standard. The unit weight of the i^{th} parameter was determined using $w_i=k/s_i$ with k=1/(sum of $1/s_i$) as the constant for proportionality. Results were interpreted as WQI≤25 for excellent quality for drinking and industrial use, 26≤WQI≤50 for a good quality for domestic and industrial use, 51≤WQI≤75 for fair quality only for irrigation and industrial use, 76≤WQI≤100 for poor quality only for irrigation use, 101≤WQI≤150 for very poor quality restricted for irrigation, WQI>150 for unfit water.

2.2.2. Biological Parameter

In each raw water sample, chlorophyll a content (Chl. a) ($µg.l^{-1}$) was obtained by measuring three optical densities (OD_{630}, OD_{645}, OD_{663}) at wavelength 630 nm, 645 nm and 663 nm respectively. Chlorophyll a content was determined as Chl $a=(11.64(OD_{663})-2.16(OD_{645})-0.10(OD_{630}))v/(VL)$ with "v" as 10 ml of the acetone and raw water mixture, "V" as the volume of the filtered water, "L" as the optical path (1.5 cm) of the spectrophotometer cell.

2.2.3. Micro-Arthropods Identification

Biological parameters of the sampled water (micro-arthropods composition, identification and counting) were carried out at the laboratory of the Biology and Physiology of the Animal Organisms (Faculty of Science, University of Douala) where the voucher water was stored. Identification and counting of zooplankton taxa were done under the stereomicroscope WILD M5 (magnification 500) and, if necessary, the optical microscope Radical model RMH-4T MNO B-201068 for small sized specimens. The specimens were identified to the species level by referring to descriptions, drawings, and photographs in available keys [18-21]. Update names and the natural environments were obtained by referring to websites [12, 17, 22, 23]. The absolute abundance of the i^{th} taxon in the V water was determined as $n_i=(n_1/v)V$ were n_1 was the absolute abundance in 50 ml of the filtrate.

2.3. Data Analysis

Data of the physicochemical parameters are given in terms of mean ± standard error (±se). Two means were compared using the Student t-test. Simultaneous comparison of several means was performed using the one-way ANOVA followed by the Student-Newman-Keuls pairwise comparisons from SigmaStat software 2.03 (SPSS, Inc., Chicago, IL). Regression equations were set up when necessary and tested using ANOVA. Correlation between parameters was determined using Pearson coefficient and the significance was determined using Student t-test. Species occurrences were given as absolute and relative frequencies. Two independents percentages were compared using Fisher's exact test. For the simultaneous comparison of several percentages, asymptotic p-value or exact p-value was determined when necessary using independent chi-square test or Fisher-Freeman-Halton test from StatXact software version 3.1. Alpha diversity analysis allowed the determination of indexes using PAST 3.05 software: richness S, Margalef's Mg, richness ratio d=S/n, Shannon-Weaver H', maximum Shannon $H'_{max}=\ln(S)$, Simpson D, Hill's first order number $N_1=e^{H'}$ (estimated number of abundants), Hill's second order number $N_2=1/D$ (estimated number of co-dominants), Hill's ratio N_2/N_1 $0\leq Hill\leq +1$, Pielou's evenness $J=H'/\ln(S)$ $0\leq J\leq +1$, and Berger-parker index n_{max}/n $0\leq I_{Berger\text{-}Parker}\leq +1$ (low value for a high diversity). Comparison of the richness was performed using the individual rarefaction procedure. Pairwise comparison of diversities (H' and D) was performed using the Student t-test. The non-parametric estimator Chao1 was used to estimate the theoretical richness T and the sampling effort was evaluated as SE=(S/T)*100. The shape of the SADs was illustrated using the rank abundance plotting. The goodness of fit of each SAD to a theoretical model was assessed by the Pearson correlation between the logarithms of the abundances and the ranks of the species ($r<-0.95$ for a poor quality of fit; $r\approx-0.95$ for an approximative quality; $r\approx-0.98$ for a satisfactory quality; and $r\geq-0.99$ for an excellent quality). Five theoretical models were tested (Broken-Stick "BS", log-linear "LL", lognormal "LN", Zipf "Z" and Zipf-Mandelbrot "ZM"). The best model was selected using AIC or BIC procedure. The estimated sample size n* was adjusted to the observed sample size n using the correction factor n/n*. Corrected model and parameters were given. Packages "Vegan" and "Ecotoxicology" from R i386.4.1.0 software helped us to adjust the SADs. BS has a single parameter x (average abundance). LL depends on the maximum abundance of the top-ranking species n_1 and the Motomura's constant m (rate of decrease in abundance by rank). In the cases of LN, for a species of rank i, we calculated the cumulative percentage linked to the rank $k_i=100(i+0.5)/(S+1)$ when the species richness S was odd or $k_i=100((i+1)+0.5)/(S+1)$ when S was even, and the probit P_i was determined using the package "Ecotoxicology". The regression between $\text{Log}(n_i)$ and P_i was $n_i=(10^b)(10^a)^{Pi}$ where "a" and "b" represented the slope and the elevation respectively of $\text{Log}(n_i)=f(P_i)$. Parameters were the maximum abundance n_1, the mean of the lognormal distribution x, the standard deviation σ and the Preston's constant m'=square root of 1/σ (rate of decrease in abundance by rank). Z was defined from two parameters ($Q=n_1(1+\beta)^\gamma$ as the normalizing constant, and γ (gamma) as the decay coefficient or the average probability of appearance of a species, with n_1 as the maximum abundance). Z model was $n_i=Q(i)^{-\gamma}$ where i was the rank of the species in decreasing order. ZM as $n_i=Q(i+\beta)^{-\gamma}$ was a generalized Z in which β (beta) (degree of the niche diversification) was added. ZM characterized evolved ecosystems, and 1/γ was the fractal dimension of the distribution [24]. Marquardt's nonlinear least squares algorithm summarized by Murthy [25], was used to estimate β and γ using $x_0=(0; 2)^T$ as the starting iteration point, $\varepsilon=1x10^{-10}$ as the tolerance value, and $\lambda_0=100$ as damping factor. For the beta diversity, the dissimilarity between sites was evaluated using the Bray-Cutis index. The overall species covariance was evaluated using the Schluter's procedure [26]. Between species correlation was evaluated using the Kendall correlation. Correlation between the presence/absence of species and the physicochemical parameters was evaluated using the point-bisserial correlation.

3. Results

3.1. Water Quality

Sites were all in the warm waters (temperature ≥20°C). Water temperature varied from 24.6-28.8℃ (standards: 20-32℃; unit weights: $\sum w_{temperature}=2.9x10^{-4}$ for each site and the pooled sites) (Table 1). Parameters with means below the upper WHO standard were: pH (slightly acidic to slightly basic, standards: 6.5-8.5 CU, pH: 6.1-7.3, $\sum w_{pH}=1.1x10^{-3}$ for each site and the pooled sites) and the SS (standards: 600-1200 $mg.l^{-1}$, records: 9-102 $mg.l^{-1}$, $\sum w_{TSS}=7.8x10^{-6}$ for each site and the pooled sites; standard for fish farming: 10-20 $mg.l^{-1}$ or >25-40 $mg.l^{-1}$) (Table 1). Parameters with means above the upper standard were Chl. a (standards: 0-0.01 $mg.l^{-1}$, records: 0.02-0.40 $mg.l^{-1}$, $\sum w_{Chl.\,a}=0.940$ for each site), and DO (standards: 5.8-7.0 $mg.l^{-1}$, records: 37.0-93.0 $mg.l^{-1}$, $\sum w_{DO}=1.3x10^{-3}$ for each site) (Table 1). NO_3^- (standards: 0-45.0 $mg.l^{-1}$, records:

0.06-1.71 mg.l^{-1}, $\sum w_{nitrates}$=2.1x10^{-4} for each site) and that of NO_2^- (standards: 0-3 mg.l^{-1}, records: 0.01-0.62 mg.l^{-1}, $\sum w_{nitrites}$=3.1x10^{-3} for each site) were below the standard limit for drinking water or fish farming (Table 1). BOD_5 (standards: 0-1500.0 mg.l^{-1}, values: 416.0-1022.0 mg.l^{-1}, and $\sum w_{BOD5}$=6.3x10^{-6} for each site), colour (standards: 5-15.0 Pt-Co, records: 11.0-103.0 Pt-Co, and $\sum w_{colour}$=6.3x10^{-4} for each site), conductivity (standards: 0-1500.0 µS.cm^{-1}, records: 416.0-1022.0 µS.cm^{-1}, $\sum w_{conductivity}$=6.3x10^{-6} for each site), NH_4^+ (standards: 0-0.2 mg.l^{-1}, values: 0.01-0.19 mg.l^{-1}, $\sum w_{ammonium}$=0.047 for each site), PO_4^{3-} (standards: 0.1-1.0 mg.l^{-1}, records: 0.04-2.16 mg.l^{-1}, $\sum w_{orthophosphate}$=9.4x10^{-3} for each site), and turbidity (standards: 5.0-20.0 FTU, records: 6.0-117.0 FTU, $\sum w_{turbidity}$=4.7x10^{-4} for each site) were above the upper standard limit (Table 1). Waters were unfit for direct drinking (proportionality constant: k=2.3x10^{-3}; Water Quality index: WQI=898.864 for the dam, WQI=752.451 for Site 2, WQI=883.808 for Site 3, WQI=1,665.883 for Site 4). The variation was not significant in Chl. a, DO, NH_4^+, NO_2^-, NO_3^- and (Table 1). Two-way ANOVA ("Sites" and "Seasons" as factors) showed that BOD_5, color, conductivity and SS were influenced by "Sites", while effects of "Seasons" and interaction were not significant (Table 1). Conductivity was lower in the dam than Sites 2 and 4 (p=1.3x10^{-3} and p=9.1x10^{-3} respectively), suggesting a drop in this parameter due to the stagnation in the dam and this parameter was higher in Site 2 (upstream of the dam) than Site 3 (p=9.1x10^{-3}) which water course was lateral to the dam (Table 1). The colour was more intense in the dam than Site 4 (p=7.5x10^{-3}) and it was more intense in Site 4 than Sites 2 and 3 (p=4.5x10^{-3} and p=7.1x10^{-3} respectively). In addition BOD_5 was lower in the dam than Site 4 (p=6.4x10^{-4}) and the parameter was higher in Site 4 than Sites 2 and 3 (p=3.1x10^{-4} and p=3.4x10^{-4} respectively), confirming a strengthening of the parameter in the dam (Table 1). SS was higher in the dam (Site 1) than Sites 2, 3 and 4 (p=3.1x10^{-3}, p=4.5x10^{-3} and p=0.040 respectively) while the parameter was lower in Site 2 than Site 4 (p=0.046) (Table 1). For PO_4^{3-} the effect of "Seasons" was significant unlike the effect of "Sites" and the interaction, the cumulative values of all sites being higher in dry season than the rainy season (Table 1). The pH presented an effect of "Sites" and the interaction effect (Table 1). The pH was higher in the dam (Site 1) than Site 2 (p=1.5x10^{-3}) and significantly lower at Site 2 than sites 3 and 4 (p=2.3x10^{-3} and p=2.8 x10^{-3} respectively) (Table 1). The pH was higher in the dry season than the rainy one in Site 3 (p=0.015). In the dry season, it was lower in the dam than Site 3 (p=0.044) and higher than Site 2 (p=0.016) (Table 1). The pH was lower in Site 2 than Sites 3 and 4 (p=1.6x10-3 and p=0.038 respectively) and the pH was higher in Site 3 than Site 4 (p=0.019) (Table 1). In the rainy season, the pH was higher in the dam than Site 2 (p=0.013) and values in Site 2 were lower than Site 4 (p=0.016) (Table 1). Temperature and turbidity showed an effect of the two factors and the interaction was not significant. The cumulative temperatures were higher in the dry season than the rainy season (p=2.9x10^{-3}) and the temperature was lower in Site 4 than the dam, Sites 2 and 3 (p=0.027, p=5.1x10^{-3} and p=0.019 respectively) (Table 1).

As for the turbidity, the cumulative values were on average lower in the dry season than the rainy season (p=0.002) and they were lower in Site 2 than Sites 3 and 4 (p=0.011 and p=0.046 respectively) (Table 1). Pooled data showed a negative correlation between the temperature and pH (Pearson's correlation: r=-0.536, Student t-test: p=0.037, n=16), colour (r=-0.759, p=0.001, n=16). It was the same between temperature and turbidity (r=-0.752, p=0.001, n=16), between pH and conductivity (r=-0.638, p=0.008, n=16), between conductivity and SS (r=-0.558, p=0.025, n=16). A positive correlation was noted between turbidity and pH (r=+0.566, p=0.022, n=16) and colour (r=+0.564, p=0.023, n=16). Other correlations were not significant.

3.2. Micro-Arthropods Composition

A total of 5,487 specimens belonged to Arthropoda von Siebold, 1848 (Table 2). These specimens corresponded to three classes (Branchiopoda (45.8%) divided into 6.1% in the dam, 30.4% in Site 2, 0.9% in Site 3, and 8.5% in Site 4), Copepoda (54.1% divided into 7.5% in the dam, 36.6% in Site 2, 0.6% in Site 3, and 9.4% in Site 4), and Ostracoda (0.05%) exclusively in the rainy season in Site 2 (Table 2).

Table 1. *Mean values of the water physico-chemical parameters in the four collection sites.*

	A. Site 1: mean ± se			**B. Site 2: Mean ± se**		
Parameters (WHO standards)	**I (n=2)**	**II (n=2)**	**Total (n=4)**	**I (n=2)**	**II (n=2)**	**Total (n=4)**
BOD_5 (Norm: 0-1500 mg.l^{-1})	52.5±7.5	27.5±17.5	40.0±10.6	15.0±5.0	22.5±2.5	18.8±3.2
Chl. a (Norm: 0-0.01 mg.l^{-1})	0.11±0.09	0.08±0.03	0.10±0.04	0.13±0.05	0.03±0.01	0.08±0.04
Colour (Norm: 5-15.0 Pt-Co)	28.0±6.0	40.0±14.0	34.0±7.1	12.0±1.0	19.5±6.5	15.8±3.4
Cond. (Norm: 0-1500 µS.cm^{-1})	488.0±72.0	511.5±56.5	499.8±38.0	844.5±54.5	897.5±124.5	871.0±57.6
DO (norm: 5.8-7.0 mg.l^{-1})	69.0±0.0	60.5±16.5	64.8±7.2	71.5±6.5	59.5±22.5	65.5±10.2
NH_4^+ (Norm: 0-0.2 mg.l^{-1})	0.12±0.05	0.07±0.04	0.09±0.03	0.08±0.04	0.050±0.005	0.05±0.02

Parameters (WHO standards)	A. Site 1: mean ± se I (n=2)	II (n=2)	Total (n=4)	B. Site 2: Mean ± se I (n=2)	II (n=2)	Total (n=4)
NO_2^- (Norm: 3 $mg.l^{-1}$)	0.16±0.05	0.33±0.29	0.25±0.13	0.20±0.15	0.08±0.07	0.14±0.07
NO_3^- (Norm: 0-45 $mg.l^{-1}$)	0.14±0.03	0.72±0.02	0.43±0.17	0.59±0.45	0.15±0.09	0.37±0.23
pH (Norm: 6.5-8.5 CU)	6.7±0.1	7.0±0.1	6.8±0.1	6.13±0.02	6.3±0.1	6.3±0.1
PO_4^{3-} (Norm: 0.01-1.0 $mg.l^{-1}$)	0.84±0.11	0.78±0.06	0.81±0.05	1.39±0.61	0.07±0.03	0.73±0.45
Temp. (Norm: 20-32 ℃)	27.7±0.2	26.8±0.2	27.3±0.3	28.3±0.5	27.4±0.4	27.8±0.4
Turbidity (Norm: 5.0-20.0 FTU)	19.5±3.5	66.0±12.0	42.8±14.4	13.5±7.5	35.0±9.0	24.3±7.8
SS (Norm: 0-1200 $mg.l^{-1}$)	90.5±11.5	74.5±12.5	82.5±8.3	17.5±3.5	41.5±0.5	29.5±7.1

Parameters (WHO standards)	C. Site 3: mean ± se I (n=2)	II (n=2)	Total (n=4)	D. Site 4: Mean ± se I (n=2)	II (n=2)	Total (n=4)
BOD_5 (Norm: 0-1500 $mg.l^{-1}$)	15.0±0.0	12.5±7.5	13.8±3.2	100.0±5.0	92.5±17.5	96.3±7.7
Chl. a (Norm: 0-0.01 $mg.l^{-1}$)	0.13±0.04	0.02±0.00	0.07±0.03	0.12±0.05	0.24±0.17	0.18±0.08
Colour (Norm: 5-15.0 Pt-Co)	24.0±0.0	27.0±16.0	25.5±6.6	70.5±19.5	85.5±17.5	78.0±11.5
Cond. (Norm: 0-1500 $\mu S.cm^{-1}$)	571.5±27.5	690.0±12.0	630.8±36.3	795.0±5.0	689.0±25.0	742.0±32.3
DO (Norm: 5.8-7.0 $mg.l^{-1}$)	74.5±18.5	52.5±11.5	63.5±10.9	77.0±0.0	64.5±2.5	70.8±3.5
NH_4^+ (Norm: 0-0.2 $mg.l^{-1}$)	0.10±0.09	0.09±0.07	0.10±0.05	0.06±0.03	0.04±0.01	0.05±0.01
NO_2^- (Norm: 0-3 $mg.l^{-1}$)	0.24±0.08	0.11±0.00	0.15±0.06	0.12±0.01	0.24±0.11	0.18±0.05
NO_3^- (Norm: 0-45 $mg.l^{-1}$)	1.21±0.50	0.11±0.01	0.66±0.38	0.74±0.46	0.33±0.16	0.53±0.23
pH (Norm: 6.5-8.5 CU)	7.2±0.1	6.7±0.1	6.9±0.2	6.7±0.3	7.0±0.1	6.9±0.2
PO_4^{3-} (Norm: 0.01-1.0 $mg.l^{-1}$)	1.61±0.55	0.60±0.12	1.10±0.37	0.40±0.07	0.47±0.00	0.44±0.03
Temp. (Norm: 20-32 ℃)	27.4±0.2	26.9±0.1	27.1±0.2	27.0±0.2	25.2±0.6	26.1±0.6
Turbidity (Norm: 5.0-20.0 FTU)	43.5±1.5	71.0±2.0	57.3±8.0	47.5±19.5	98.5±18.5	73.0±18.4
SS (Norm: 0-1200 $mg.l^{-1}$)	26.0±17.0	48.0±7.0	37.0±9.8	48.0±7.0	68.5±9.5	58.3±7.6
Two-way ANOVA	Rivers: df=3; Seasons: df=1; Rivers x Seasons: df=3; residual: df=8; Total variation: df=15					

***Table 1**. Continued.*

Source of variation	BOD_5	Chl. a	Color	Cond.	DO	NH_4^+	NO_2^-	NO_3^-
Sites	$1.2x10^{-4}$ *	0.493 ns	0.005 *	0.001 *	0.943 ns	0.649 ns	0.875 ns	0.776 ns
Seasons	0.354 ns	0.574 ns	0.314 ns	0.612 ns	0.166 ns	0.349 ns	0.924 ns	0.139 ns
Sites x Seasons	0.463 ns	0.447 ns	0.963 ns	0.354 ns	0.956 ns	0.935 ns	0.640 ns	0.111 ns

Source of variation	pH	PO_4^{3-}	Temp	Turb.	TSS
Sites	0.002 *	0.241 ns	0.007 *	0.014 *	0.003 *
Seasons	0.557 ns	0.024 *	0.003 *	0.002 *	0.108 ns
Sites x Seasons	0.026 *	0.116 ns	0.385 ns	0.526 ns	0.211 ns

I: Dry season; II: rainy season; *: significant probability ($p<0.05$). Suspended Solids norm for fish farming: 10-20 $mg.l^{-1}$ or >25-40 $mg.l^{-1}$

Eight orders were identified (Anomopoda (38.3%), Calanoida (9.9%), Ctenopoda (6.3%), Cyclopoida (43.9%), Haplopoda (0.3%), Harpacticoida (0.2%), Onychopoda (0.9%) exclusively in the dam in both seasons, and Podocopida (0.05%) exclusively in Site 2 in the rainy season) (Table 2). Anomopoda and Cyclopoida were recorded in all sites in both seasons. Harpacticoida was recorded in the rainy season in each site (Table 2). In Sites 2 and 4, Haplopoda was recorded in the dry season (Table 2). Anomopoda was the most recorded while Podocopida was the less recorded (Table 2).

Twenty families were recorded (Table 2): Aetideidae (6.8%) exclusively in the dam, Centropagidae (0.09%) exclusively in the dam, Chydoridae (27.8%) in all sites, Cercopagididae (0.07%) exclusively in the dam, Cyclopidae (43.0%) in all sites, Clausocalanidae (1.7%) in Sites 2 and 4, Cyclopettidae (0.2%) in Sites 1 and 2, Cyprididae (0.05%) exclusively in the rainy season in Site 2, Daphniidae (4.5%) in all sites, Diaptomidae (0.8%) in the dam and Site 4, Halicyclopidae (0.7%) in the dam and Site 4; Harpacticidae (0.2%) exclusively in the rainy season in the dam and Site 4; Ilyocryptidae (0.4%) not recorded in Site 2; Laophontidae (0.02%) exclusively in the rainy season in Site 4, Leptodoridae (0.3%) in both seasons in the dam and in the dry season in Site 4, Macrothricidae (1.0%) in both seasons in the dam and in the dry season in Site 4; Moinidae (4.7%) not recorded in Site 3; Polyphemidae (0.8%) exclusively in the dam; Pseudodiaptomidae (0.5%) exclusively in the rainy season in the dam and Site 4; and Sididae (6.3%) not recorded in Site 3 (Table 2). Then Cyclopidae was the most recorded family and Laophontidae was the less recorded (Table 2).

Fithty-seven genera, 82 species and five morphospecies (Centropagidae "Undetermined 1" exclusively in the rainy season in the dam, Calanoida "Undetermined 2" common to both seasons in Sites 2 and 4, Cyclopidae "Undetermined 3" common to all sites, Halicyclopidae "Undetermined 4" common to the dam in the dry season and Site 4 in the rainy season, and the Laophontidae "Undetermined 5" exclusively in the rainy season in Site 4). Chydoridae was the most species-rich family (42.5%), followed by Cyclopidae (16.0%), Daphniidae (11.5%), Diaptomidae (5.7%), Moinidae (4.6%), Hyocryptidae (3.4%), Sididae (2.3%). Other families were represented each by one species (Table 2).

The species exclusively in a single site were numerous and fairly represented (41.4% of the total richness, 13.9% of the total collection, mean ±se: 21±11). Exclusively in the dam, 19 species were recorded (12.8% of the total collection, 35±19). The Centropagidae "Undetermined 1" was exclusively in the wet season. Recorded species were six species exclusively in the dry season (*Alona quadrangularis*, *Acroperus angustatus*, *Chydorus gibbus*, *Drepanothrix dentata*, *Paracyclops* sp., and *Simocephalus exspinosus*), two species exclusively in the wet season (*Bythotrephes longimanus*, and *Daphnia curvirostris*), and 11 species common to both seasons: *Daphnia lumholtzi*, *Diaphanosoma brachyurum*, *Diaptomus* sp., *Ilyocryptus agilis*, *Karualona karua*, *Leydigia acanthocercoides*, *Moinodaphnia macleayi*, *Polyphemus pediculus*, *Scapholeberis kingi*, *Senecella calanoides*, and *Simocephalus vetulus*) (Table 2).

Exclusively in Site 2, three species were recorded (*Leydigia quadrangularis* exclusively in dry season with 0.04%, and *Stenocypris* exclusively in rainy season, and *Acroperus aduncus* simultaneously in both seasons) (Table 2). Exclusively in Site 3 two species were recorded (0.07%) (*Ceriodaphnia* sp. exclusively in the rainy season, and *Ilyocryptus sordidus* simultaneously in both seasons) (Table 2). Exclusively in Site 4, 11 species and the Laophontidae "Undetermined 5" were recorded (five species i.e. 0.24% exclusively in the dry season, two species i.e. 0.07%) exclusively in the rainy season, and four species i.e. 0.42% common to both seasons) (Table 2).

Table 2. *Absolute abundances of the micro-arthropods in the collection sites.*

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Branchiopoda Latreille, 1817 / Anomopoda G. O. Sars, 1865 / Chydoridae Dybowski & Grochowski, 1894													
Acroperus aduncus ■, ●, #	-	-	-	4	10	14	-	-	-	-	-	-	14 (0.3)
Ac. angustatus #	1	-	1	-	-	-	-	-	-	-	-	-	1 (0.02)
Ac. harpae ■, ●, #	-	-	-	-	-	-	-	-	-	2	2	4	4 (0.07)
Alona costata ●, #	409	11	420	14	28	42	2	5	7	19	3	22	491 (8.9)
Al. guttata #	21	-	21	1	10	11	1	1	2	7	-	7	41 (0.7)
Al. natalensis #	-	-	-	-	-	-	-	-	-	4	4	8	8 (0.1)
Al. protzi #	7	-	7	2	17	19	-	-	-	-	-	-	26 (0.5)
Al. quadrangularis ■, ●, #	8	-	8	-	-	-	-	-	-	-	-	-	8 (0.1)

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Al. rectangula •, #	11	5	16	4	5	9	-	-	-	-	-	-	25 (0.5)
Al. rustica #	4	4	8	4	8	12	-	2	2	4	6	10	32 (0.6)
Alonella excisa #	5	11	16	3	-	3	-	-	-	5	-	5	24 (0.4)
Biapertura affinis #	4	3	7	-	-	-	-	-	-	3	2	5	12 (0.2)
Bi. intermedia #	10	12	22	29	5	34	4	-	4	-	-	-	60 (1.1)
Camptocercus rectirostris #	-	4	4	2	3	5	-	-	-	2	-	2	11 (0.2)
Chydorus gibbus #,	3	-	3	-	-	-	-	-	-	-	-	-	3 (0.05)
Ch. ovalis •, #	26	2	28	-	-	-	1	1	2	14	8	22	52 (0.9)
Ch. piger #,	13	-	13	-	-	-	1	-	1	21	1	22	36 (0.7)
Ch. sphaericus ■, •, #	10	2	12	4	-	4	5	-	5	15	-	15	36 (0.7)
Euryalona orientalis #	2	9	11	1	-	1	-	-	-	-	-	-	12 (0.2)
Karualona karua #	7	15	22	-	-	-	-	-	-	-	-	-	22 (0.4)
Kurzia latissima #	12	-	12	-	-	-	1	-	1	8	1	9	22 (0.4)
Ku. longirostris #	21	-	21	13	5	18	2	-	2	19	-	19	60 (1.1)
Leberis diaphanus #	2	4	6	2	-	2	-	-	-	2	-	2	10 (0.2)
Leydigia acanthocercoides •, #	8	14	22	-	-	-	-	-	-	-	-	-	22 (0.4)
Ly. quadrangularis #	-	-	-	2	-	2	-	-	-	-	-	-	2 (0.04)
Nicsmirnovius eximius #	20	11	31	11	3	14	-	-	-	6	1	7	52 (0.9)
Oxyurella singalensis #	2	-	2	-	-	-	-	-	-	2	-	2	4 (0.07)
Picripleuroxus denticulatus #	6	4	10	25	12	37	1	3	4	74	47	121	172 (3.1)
Pi. laevis #	13	23	36	6	3	9	2	-	2	15	12	27	74 (1.3)

***Table 2**. Continued.*

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Branchiopoda Latreille, 1817 / Anomopoda G. O. Sars, 1865 / Chydoridae Dybowski & Grochowski, 1894 (Continued)													
Pi. striatus #	7	7	14	-	-	-	-	-	-	5	3	8	22 (0.4)
Pleuroxus aduncus •, #	17	-	17	2	3	5	-	-	-	21	3	24	46 (0.8)
Pl. trigonellus #	4	4	8	4	5	9	-	2	2	14	4	18	37 (0.7)
Pl. uncinatus #	4	2	6	1	5	6	-	-	-	-	-	-	12 (0.2)
Rhynchotalona falcata #	-	-	-	-	-	-	-	-	-	6	1	7	7 (0.1)
R. kistarae #,	8	9	17	4	3	7	-	-	-	11	1	12	36 (0.7)
Rhynchotalona sp. #	-	-	-	-	-	-	-	-	-	1	-	1	1 (0.02)
Tretocephala ambigua #	9	2	11	4	3	7	-	-	-	6	3	9	27 (0.5)
Branchiopoda / Anomopoda / Daphniidae Straus, 1820													
Ceriodaphnia cornuta •, #	2	3	5	1	3	4	-	-	-	-	3	3	12 (0.2)
Ce. megops #	-	-	-	-	-	-	-	-	-	1	-	1	1 (0.02)

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Ce. quadrangula [•, #]	-	-	-	-	-	-	-	-	-	2	-	2	2 (0.04)
Ceriodaphnia sp. [•, #]	-	-	-	-	-	-	1	-	1	-	-	-	1 (0.02)
Daphnia curvirostris [#]	-	2	2	-	-	-	-	-	-	-	-	-	2 (0.04)
Da. lumholtzi [#]	69	46	115	-	-	-	-	-	-	-	-	-	115 (2.1)
Da. obtusa [#]	-	-	-		2	2	-	-	-	1		1	3 (0.05)
Daphnia sp. [■, •, #]	-	-	-	13	23	36	4	9	13	30	17	47	96 (1.7)
Simocephalus exspinosus [•, #]	4	-	4	-	-	-	-	-	-	-	-	-	4 (0.07)
Sm. vetulus [•, #]	2	8	10	-	-	-	-	-	-	-	-	-	10 (0.2)
Branchiopoda / Anomopoda / Ilyocryptidae Smirnov, 1976													
Ilyocryptus acutifrons [•, #]	7	-	7	-	-	-	-	-	-	1	-	1	8 (0.1)
I. agilis [•, #]	6	3	9	-	-	-	-	-	-	-	-	-	9 (0.2)
I. sordidus [•, #]	-	-	-	-	-	-	2	1	3	-	-	-	3 (0.05)
Branchiopoda / Anomopoda / Macrothricidae Norman & Brady, 1867													
Drepanothrix dentata [#]	1	-	1	-	-	-	-	-	-	-	-	-	1 (0.02)
Streblocerus serricaudatus [#]	44	9	53	-	-	-	-	-	-	1	-	1	54 (1.0)
Branchiopoda / Anomopoda / Moinidae Goulden, 1968													
Moina brachiata [•, #]	46	25	71	1	-	1	-	-	-	3	-	3	75 (1.4)
Mo. macrocopa [#]	53	26	79	-	-	-	-	-	-	3	4	7	86 (1.6)
Mo. micrura [•, #]	53	13	66	1	-	1	-	-	-	1	-	1	68 (1.2)
Moinodaphnia macleayi [#]	1	28	29	-	-	-	-	-	-	-	-	-	29 (0.5)
Branchiopoda / Ctenopoda G. O. Sars, 1865 / Sididae Baird, 1850													
Diaphanosoma brachyurum [■, •, #]	1	10	11	-	-	-	-	-	-	-	-	-	11 (0.2)
Di. sarsi [#]	208	100	308	13	5	18	-	-	-	6	3	9	335 (6.1)

Table 2. *Continued.*

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Branchiopoda / Haplopoda G. O. Sars, 1865 / Leptodoridae Lilljeborg, 1861													
Leptodora kindtii [•, #]	3	12	15	-	-	-	-	-	-	2	-	2	17 (0.3)
Branchiopoda / Onychopoda G. O. Sars, 1865 / Cercopagididae Mordukhai-Boltovskoi, 1968													
Bythotrephes longimanus [■, •, #]	-	4	4	-	-	-	-	-	-	-	-	-	4 (0.07)
Branchiopoda / Onychopoda / Polyphemidae Baird, 1845													
Polyphemus pediculus [•, #]	43	2	45	-	-	-	-	-	-	-	-	-	45 (0.8)
Copepoda Milne Edwards, 1840 / Calanoida Sars G. O., 1903 / Aetideidae Giesbrecht, 1892													
Senecella calanoides [•, #]	55	320	375	-	-	-	-	-	-	-	-	-	375 (6.8)
Copepoda / Calanoida / Centropagidae Giesbrecht, 1892													
Undetermined 1 [■, •, #]	-	5	5	-	-	-	-	-	-	-	-	-	5 (0.09)

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Copepoda / Calanoida / Undetermined family													
Undetermined 2 [■, •, #]	-	-	-	15	23	38	-	-	-	38	18	56	94 (1.7)
Copepoda / Calanoida / Diaptomidae Baird, 1850													
Diaptomus sp. [#]	6	5	11	-	-	-	-	-	-	-	-	-	11 (0.2)
Paradiaptomus sp. [#]	-	-	-	-	-	-	-	-	-	-	3	3	3 (0.05)
Scapholeberis kingi [#]	11	10	21	-	-	-	-	-	-	-	-	-	21 (0.4)
Thermodiaptomus sp. [#]	-	-	-	-	-	-	-	-	-	4	-	4	4 (0.07)
Tropodiaptomus sp. [#]	-	-	-	-	-	-	-	-	-	5	-	5	5 (0.09)
Copepoda / Calanoida / Pseudodiaptomidae Sars G. O., 1902													
Pseudodiaptomus sp. [■, •, #]	-	22	22	-	5	5	-	-	-	-	-	-	27 (0.5)
Copepoda / Cyclopoida Burmeister, 1834 / Cyclopettidae Mart ńez Arbizu, 2000													
Limnoithona sinensis [•, #]	-	10	10	-	-	-	1	1	2	-	-	-	12 (0.2)
Copepoda / Cyclopoida / Cyclopidae Rafinesque, 1815													
Abdiacyclops sp. [#]	-	-	-	7	-	7	-	-	-	-	28	28	35 (0.6)
Afrocyclops sp. [#]	44	26	70	2	8	10	-	-	-	6	6	12	92 (1.7)
Allocyclops sp. [#]	-	-	-	-	-		-	-	-	3	1	4	4 (0.07)
Cryptocyclops sp. [#]	14	24	38	5	-	5	-	-	-	8	5	13	56 (1.0)
Ectocyclops sp. [#]	164	187	351	23	96	119	-	3	3	89	17	106	579 (10.6)
Eucyclops sp. [■, #]	11	-	11	2	10	12	-	-	-	8	1	9	32 (0.6)
Mesocyclops sp. [#]	157	195	352	14	35	49	-	3	3	24	4	28	432 (7.9)
Microcyclops sp. [#]	4	48	52	1	-	1	-	-	-	5	1	6	59 (1.1)
Paracyclops sp. [#]	3	-	3	-	-	-	-	-	-	-	-	-	3 (0.05)
Thermocyclops sp. [#]	63	57	120	-	15	15	-	3	3	11	8	19	157 (2.9)
Tropocyclops sp. [#]	255	-	255	18	63	81	-	6	6	58	12	70	412 (7.5)
Undetermined 3 [■, •, #]	116	168	284	27	38	65	-	17	17	69	64	133	499 (9.1)

Table 2. *Continued.*

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Copepoda / Cyclopoida / Halicyclopidae Kiefer, 1927													
Undetermined 4 [•, #]	11	9	20	-	-	-	-	-	-	19	-	19	39 (0.7)
Copepoda / Harpacticoida Sars G. O., 1903 / Harpacticidae Dana, 1846													
Harpacticella sp. [#]	-	7	7	-	5	5	-	-	-	-	-	-	12 (0.2)
Copepoda / Harpacticoida / Laophontidae Scott T., 1904													
Undetermined 5 [■, •, #]	-	-	-	-	-	-	-	-	-	-	1	1	1 (0.02)
Ostracoda Latreille, 1802 / Podocopida Sars, 1866 / Cyprididae Baird, 1845													
Stenocypris major [#]	-	-	-	-	3	3	-	-	-	-	-	-	3 (0.05)

Classes /Orders / Families/ Species	Site 1 (Dam)			Site 2			Site 3			Site 4			
	I	II	III	I	II	III	I	II	III	I	II	III	Global (%)
Total	2,131	1,542	3,673	28	57	85	684	298	982	285	462	747	5,487 (100.0)

I: dry season; II: rainy season; III: pooled seasons; ▪: marine water; •: brackish water; #: freshwater.

The pooled data from the two seasons gives a total of 30 species (4.9%, 9±3) in the dry season, and 23 species (9.1%, 22±14) in the rainy season.

Ubiquitous species were common to at least two sites. Six species were common to the dam and Site 2 (*Al. protzi, Al. rectangular, Eu. orientalis*, *Harpacticella* sp., *Pl. uncinatus*, and *Pseudodiaptomus* sp.) (Table 2). *Li. sinensis* was common to the dam and Site 3 (Table 2). Eight species were common to the dam and Site 4 (*Biapertura affinis*, *Ilyocryptus acutifrons*, *Leptodora kindtii*, *Mo. macrocopa*, *Neocyclops* sp., *Oxyurella singalensis*, *Pl. striatus*, and *Streblocerus serricaudatus*) (Table 2). Three species were common to Sites 2 and 4 (*Abdiacyclops* sp., *Da. obtusa* and the Calanoida "Undetermined 2") (Table 2). The Halicyclopidae "Undetermined 4" was common to the dam and Site 4 (Table 2). A total of 20 ubiquitous species were common to three sites. Two species were common to the dam, Site 2 and Site 3 (*Bi. intermedia* and *Di. sarsi*) (Table 2). Thirteen species were common to the dam, Site 2 and Site 4 (*Afrocyclops* sp., *Alonella excisa*, *Camptocercus rectirostris*, *Ceriodaphnia cornuta*, *Cryptocyclops* sp., *Eucyclops* sp., *Microcyclops* sp., *Moina brachiata*, *Mo. micrura*, *Nicsmirnovius eximius*, *R. kistarae*, *Pleuroxus aduncus*, and *Tretocephala ambigua*) (Table 2). Five species were common to the dam, Site 3 and Site 4 (*Chydorus piger*, *Ch. ovalis*, *Daphnia* sp., *Kurzia latissima*, and *Le. diaphanous*) (Table 2). A total of 13 ubiquitous species were common to the four sites (*Alona costata*, *Al. guttata*, *Al. rustica*, *Ch. sphaericus*, *Ectocyclops* sp., *Kurzia longirostris*, *Mesocyclops* sp., *Pleuroxus denticulatus*, *Pl. laevis*, *Pl. trigonellus*, *Thermocyclops* sp., *Tropocyclops* sp., and the Cyclopidae "Undetermined 3") (Table 2). The most recorded species were *Ectocyclops* sp. (10.6%), *Cyclops* sp. (9.1%), *Al. costata* (8.9%), *Mesocyclops* sp. (7.9%), *Tropocyclops* sp. (7.5%), *Se. calanoides* (6.8%), *Di. sarsi* (6.1%), Other species were each represented by less than 4.0% (Table 2).

Based on the water environment, 54 freshwater species (60.9% of the total collection, 62±16) and 33 tolerant species (39.1%, 65±22) were recorded (Tables 2 and 3A). Fifty-four freshwater specialists were divided into 28 Chydoridae [12], 10 Cyclopidae [12, 22], one Cyprididae [12, 23], four Daphniidae [12], five Diaptomidae [12, 22], one Harpacticidae [12, 22], two Macrothricidae [12], two Moinidae [12]. and one Sididae [12]. Chydoridae were *Acroperus angustatus, Alona guttata, Al. natalensis, Al. protzi, Al. rustica, Alonella excisa, Biapertura affinis, Bi. intermedia, Camptocercus rectirostris, Chydorus gibbus, Ch. piger, Euryalona orientalis, Karualona karua, Kurzia latissima, Ku. longirostris, Leberis diaphanous, Leydigia quadrangularis, Nicsmirnovius eximius, Oxyurella singalensis, Picripleuroxus denticulatus, Pi. laevis, Pi. striatus, Pleuroxus trigonellus, Pl. uncinatus, Rhynchotalona falcate, R. kistarae, Rhynchotalona* sp. and *Tretocephala ambigua* [12] (Table 2). Cyclopidae were *Abdiacyclops* sp., *Afrocyclops* sp., *Allocyclops* sp., *Cryptocyclops* sp., *Ectocyclops* sp., *Mesocyclops* sp., *Microcyclops* sp., *Paracyclops* sp., *Thermocyclops* sp., and *Tropocyclops* sp. [12, 22] (Table 2). The Cyprididae species was *Stenocypris major* [12, 23] (Table 2). Daphniidae were *Ceriodaphnia megops, Daphnia curvirostris, Da. lumholtzi*, and *Da. obtusa* [12] (Table 2). Diaptomidae were (*Diaptomus* sp., *Paradiaptomus* sp., *Scapholeberis kingi, Thermodiaptomus* sp., and *Tropodiaptomus* sp. [12, 22] (Table 2). The Harpacticidae was *Harpacticella* sp. [12, 22] (Table 2). Macrothricidae were *Drepanothrix dentata*, and *Streblocerus serricaudatus* [12] (Table 2). Moinidae were *Moina macrocopa*, and *Moinodaphnia macleayi* [12] (Table 2). The Sididae was *Diaphanosoma sarsi* [12] (Table 2). Tolerant species were able to develop in at least two water environments. Twenty species and morphospecies were specialists of the brackish water and freshwater (*Alona costata, Al. rectangular, Ceriodaphnia cornuta, Ce. quadrangular, Ceriodaphnia* sp., *Chydorus ovalis*, Halicyclopidae Undetermined 4, *Ilyocryptus acutifrons, I. agilis, I. sordidus, Leptodora kindtii, Leydigia acanthocercoides, Limnoithona sinensis, Moina brachiata, Mo. micrura, Pleuroxus aduncus, Polyphemus pediculus, Senecella calanoides, Simocephalus exspinosus, Sm. vetulus*) [12] (Table 2). One species *Eucyclops* sp. is frequently found in the marine water and freshwater environments [12, 22] (Table 2). Twelve species and morphospecies were specialists of the marine water, brackish water and freshwater (*Acroperus aduncus, Ac. harpae, Alona quadrangularis, Bythotrephes longimanus*, Calanoida Undetermined 2, Centropagidae Undetermined 1, *Chydorus sphaericus*, Cyclopidae Undetermined 3, *Daphnia* sp., *Diaphanosoma brachyurum*, Laophontidae Undetermined 5, *Pseudodiaptomus* sp.) [12, 22] (Table 2). Five species exclusively in the dry season were specialists of the brackish and freshwater (Tables 2 and 3B). Four species and morphospecies exclusively in the rainy season were specialists of the marine, brackish and freshwater (Tables 2 and 3B). Sixteen species simultaneously in both seasons were specialists of yje brackish and freshwater (Tables 2 and 3B). *Ac. aduncus* was recorded in the wet season and was a specialist of marine, brackish and freshwater [12]. Six species in both seasons were specialists of the marine, brachish and freshwater (Tables 2 and 3B). *Eucyclops* sp. in both seasons was able to develop in the marine and freshwater (Tables 2 and 3B).

3.3. Alpha Diversity and Community Structure

The richness was low in all cases (Table 4). The lowest richness was noted in Site 3 in dry season (Margalef's index: Mg=3.901, richness ratio: d=0.500) and in rainy season (Mg=3.215, d=0.246) (Table 4). The highest richness was in the dam in dry season (Mg=7.698; d=0.028) and the pooled seasons (Mg=8.040, d=0.018) (Table 4). The diversity was high in all sites (Table 4), corroborating information from Simpson index (Table 4). Pairwise comparison of the diversity indexes showed in all cases, a high diversity in dry season than the rainy season except in Site 3 was the difference was not significant (Table 4). Between sites, differences were significant except in the rainy season and the pooled seasons between the dam and Site 4. Not significant differences were noted in both seasons between the dam and Site 2 (Table 4). Based on the Chao1 estimator, the sampling success was maximal (100.0%) in the rainy season in the dam and Site 2 and in the pooled seasons (Table 4). It was acceptable (close to 98.0%) in the dry season in the dam and in the pooled seasons in Site 3 (Table 4). In other cases, it was less than 98.0% (Table 4). Highly even assemblages were noted and all assemblages were lowly dominated by a few species (Table 4). Individual rarefaction curves approached the plateaus of saturation in both seasons in the dam, and in the pooled seasons (Figure 2). For a standard sample of 11 specimens, assemblage was lowly diverse in the rainy season in the dam and Site 3 ($E(S_{n=11})=7\pm1$ species respectively), and highly diverse in the dry season in the dam (($E(S_{n=11})=9\pm1$ species). The other distributions occupied the intermediate position between the two extremes (Table 4 and Figure 2).

The species abundance distributions (SADs) of the pooled assemblage presented a very weak concavity appearance despite it was close to the Fisher's log-series model (pooled sites in both seasons: α=14.68, x=0.9973, $p=1.3x10^{-61}$ (Figure 3A); pooled sites in (dry season: α=14.73, x=0.9953, $p=1.4x10^{-9}$ (Figure 3B); pooled sites in rainy season: α=14.03, x=0.9941, $p=1.3x10^{-27}$ (Figure 3C)). Other species concerned 49 species in the pooled distribution (Figure 3A), 41 species in the pooled dry season (Figure 3B) and 34 species in the pooled rainy season (Figure 3C). These species are listed in Table 2. A similar shape was noted in all cases. Adjustment to the log-series model was significant in each season in the dam (dry season: α=11.47, x=0.995, $p=9.4x10^{-4}$ (Figure 4A); rainy season: α=10.14, x=0.994, $p=3.5x10^{-12}$ (Figure 4B); pooled seasons: α=11.64, x=0.997, $p=3.1x10^{-52}$ (Figure 4C)). Adjustment was not significant in Site 2 (dry season: α=11.34, x=0.962, p=0.700 (Figure 4J); rainy season: α=7.808, x=0.983, p=0.822 (Figure 4K); pooled seasons: α=9.622, x=0.9873, p=0.128 (Figure 4L)). Adjustment was significant in Site 3 (dry season: α=11.14, x=0.715, p=0.934 (Figure 4D); rainy season: α=5.921, x=0.906, p=0.978 (Figure 4E); pooled seasons: α=8.912, x=0.905, p=0.999 (Figure 4F)), in Site 4 (dry season: α=12.41, x=0.982, p=0.969 (Figure 4G); rainy season: α=10.29, x=0.967, p=0.962 (Figure 4H); pooled seasons: α=12.29, x=0.988, p=0.216 (Figure 4I)). In the dam, other species category concerned 47 species in the dry season (Figure 4A), 37 species in the rainy season (Figure 4B), and 54 species in the pooled seasons (Figure 4C). In Site 2, other species category was 24 species in the dry season (Figure 4D), 19 species in the rainy season (Figure 4E), and 29 species in the pooled seasons (Figure 4F). These species are presented in Table 2. In Site 3, other species category in the pooled seasons concerned eight species (Figure 4I). In Site 4, the same category concerned 37 species in the dry season (Figure 4J), 22 species in the rainy season (Figure 4K), and 41 species in the pooled distribution (Figure 4L and Table 2). Abundant species were obtained by referring to their high abundances in the SADs (Figures 3 and 4). Their numbers were obtained by referring to Hill's N_1 index (Table 4) (Tables 2 and 3). Forty-eight species were abundant (nine in the rainy season in Site 3 to 31 species in the pooled assemblage) (Table 4, Figure 4). In the dam, amongst the 67 species (16 exclusively in the dry season, seven species exclusively in the rainy season, and 44 common to both seasons, Figures 4A and 4B), 27 abundant species and 40 rare species.

3.4. Beta Diversity and Adjustment of SADs

Although cosmopolitan species were recorded, median and high dissimilarities exist. In the dam (Site 1), the dissimilarity was median between assemblage in the dry season and that in rainy season, assemblage in dry season and the pooled seasons in Site 4 (Table 5). The pooled seasons in the dam showed a median dissimilarity compared to the rainy season in pooled sites (Table 5). The dissimilarity was high between the dry season and the pooled season (Table 5). In Site 2, the dissimilarity was median between the dry season and the pooled seasons, and between the rainy season and the pooled seasons (Table 5). The pooled seasons in the same site showed a median dissimilarity compared to the pooled seasons in Site 4 (Table 5). In Site 3 a median dissimilarity was noted between rainy season and the pooled seasons (Table 5). A high dissimilarity was noted between the dry season and the pooled seasons (Table 5). In Site 4 a median dissimilarity was noted between the dry season and the rainy season (Table 5). A median dissimilarity was noted between the rainy season and the pooled seasons in Site 4 (Table 5). A high dissimilarity was noted between the dry season and the pooled seasons in Site 4 (Table 5). Cluster analysis showed two groups at a Jaccard similarity between 0.24 and 0.40: Site 3 in both seasons and pooled seasons for the first group and the three other sites for the second group (Figure 5).

Adjustment of SADs to theoretical models showed in all cases a poor quality of fit (Pearson correlation r<-0.95) (Site 1: dry season: r=-0.635, Student t-test: $p=5.1x10^{-8}$, rainy season: r=-0.619, $p=1.3x10^{-6}$, pooled seasons: r=-0.674, $p=4.0x10^{-10}$;

Site 2: dry season: r=-0.877, p=4.9x10^{-13}, rainy season: r=-0.726, p=2.6x10^{-6}, pooled seasons: r=-0.767, p=3.1x10^{-9}; Site 3: dry season: r=-0.866, p=6.2x10^{-5}, rainy season: r=-0.795, p=6.7x10^{-4}, pooled seasons: r=-0.774, p=3.8x10^{-5}; Site 4: dry season: r=-0.746, p=5.1x10^{-10}, rainy season: r=-0.698, p=3.2x10^{-6}, pooled seasons: r=-0.707, p=2.3x10^{-9}).

Based on AIC and BIC values (Table 7), the SAD in the dam and the dry season fitted ZM (Table 6A, Figures 3 and 4) with a low decay coefficient, a high niche diversification and a median fractal dimension (deviance: 37.052; normalization constant: Q=2131, maximum abundance: n_1=409, decay coefficient: γ=0.994; niche diversification: β=1.361; fractal dimension: 1/γ=1.006; correction factor: 0.282; corrected ZM: $n_i=602(i+1.361)^{-0.994}$). ZM fitted the SAD in the wet season in the dam (Table 6A) with a high decay coefficient, a high niche diversification and a low fractal dimension (deviance: 54.365; Q=1542; n_1=320; γ=1.245; β=1.295; 1/γ=0.803; correction factor: 0.505; corrected ZM: $n_i=779(i+1.295)^{-1.245}$). It was the same in the pooled seasons (deviance: 202.29; Q=3673; n_1=420; γ=0.961; β=1.367; 1/γ=1.040; correction factor: 0.253; corrected ZM: $n_i=929(i+1.367)^{-0.961}$ (Table 6A). In Site 2, LL fitted assemblage in the dry season with a median environmental constant (Table 6B) (n_1=29; Motomura's constant: m=0.906; deviance: 6.966; correction factor: 5.570; corrected LL: $n_i=160.825(0.906)^{i}$). ZM fitted assemblage in the wet season (Table 6B) with a high decay coefficient, a low niche diversification, and a low fractal dimension (deviance: 4.185; Q=462, n_1=96, γ=1.795; β=0.893; 1/γ=0.557; correction factor: 1.159; corrected ZM: $n_i=535(i+0.893)^{-1.795}$). LN fitted the pooled seasons' assemblage in Site 2 (Table 6B), with a low Preston's constant (n_1=119; deviance=13.751; mean: x=0.941; standard deviation: σ=0.499; Preston's constant: m'=0.363; correction factor: 1.062; corrected LN: $n_i=6516(0.273)^{P_i}$ with P_i as probit of the i^{th} species). In Site 3, LL fitted assemblage in the dry season (Table 6C), with a median environmental constant (n_1=5; deviance: 1.580; environmental constant: m=0.877; deviance: 1.600; correction factor: 1.047; corrected LL: $n_i=4.672(0.877)^{i}$ with i as the species ranks) (Table 7). BS fitted assemblage in the rainy season (Table 6C) (mean ± se: x=4±1; correction factor: 2.503; deviance: 3.743; corrected BS: n_i=5.007((sum from i to S of 1/(29-i)) with S as the species richness) (Table 7). Z fitted the pooled seasons' assemblage (Table 6C) with a very low negative decay coefficient (γ<0) (n_1=17; Q=85; deviance: 1.744; γ=-0.902; correction factor: 0.241; corrected Z: $n_i=21(i)^{-1.782}$). In Site 4, ZM fitted assemblage in the dry season (Table 6D), with a high decay coefficient, a low level of niche diversification, and a low fractal dimension (deviance: 13.54; Q=684, n_1=89, γ=1.811; β=0.868; 1/γ=0.552; correction factor: 1.138; corrected ZM: $n_i=779(i+0.868)^{-1.811}$) (Table 7). It was the same in the rainy season (Table 6D) (deviance: 5.089; Q=298, n_1=64, γ=1.867; β=0.763; 1/γ=0.536; correction factor: 1.167; corrected ZM: $n_i=348(i+0.763)^{-1.867}$). It was also the same in the pooled seasons (Table 6D) with a high decay coefficient, a low niche diversification, and a low fractal dimension (deviance: 30.835; Q=982, n_1=133, γ=1.710; β=1.00; 1/γ=0.585; correction factor: 1.050; corrected ZM: $n_i=1031(i+1.00)^{-1.710}$).

3.4.1. Correlation Between Species

A global positive net association was noted (Schluter's variance ratio: VR=14.936, W=716.929, df=86, p<0.001), in the dam (VR=21.889, W=262.667, df=66, p<0.001), in Site 2 (VR=9.390, W=112.680, df=41, p<0.001), in Site 3 (VR=19.160, W=229.915, df=20, p<0.001), and in Site 4 (VR=14.063, W=168.755, df=53, p<0.001). The Kendall correlation makes it possible to define a negative correlated species and a positively correlated ones. As part of group 1, *Afrocyclops* sp. was correlated with five species (Table 7A).

Table 3. *Absolute and relative abundances of the recorded species according to the natural water environment.*

Environments	Site 1 (dam)			Site 2			Site 3		
	I (%)	II (%)	Total (%)	I (%)	II (%)	Total (%)	I (%)	II (%)	Total (%)
A. Freshwater specialists (54 species, 62.1% of the total species richness)									
n (%)	1,282 (23.4)	894 (16.3)	2,176 (39.7)	197 (3.6)	314 (5.7)	511 (9.3)	12 (0.2)	23 (0.4)	35 (0.6)
S (%)	39 (44.8)	31 (35.6)	42 (48.3)	25 (28.7)	22 (25.3)	29 (33.3)	7 (8.0)	8 (9.2)	13 (14.9)
Min.-Max.	1-255	2-195	1-352	1-29	2-96	1-119	1-4	1-6	1-6
Mean ± se	33±10	29±9	52±14	8±2	14±5	18±5	2±0	3±1	3±0
B. Tolerant species (33 species, 37.9% of the total species richness)									
B1. Freshwater and brackish water specialists (20 species, 23.0% of the total species richness)									
n (%)	703 (12.8)	437 (8.0)	1,140 (20.8)	23 (0.4)	39 (0.7)	62 (1.1)	7 (0.1)	8 (0.1)	15 (0.3)
S (%)	16 (18.4)	14 (16.1)	17 (19.5)	6 (6.9)	4 (4.6)	6 (6.9)	5 (5.7)	4 (4.6)	5 (5.7)
Min.-Max.	2-409	2-320	4-420	1-14	3-28	1-42	1-2	1-5	1-7

Environments	Site 1 (dam)			Site 2			Site 3		
	I (%)	**II (%)**	**Total (%)**	**I (%)**	**II (%)**	**Total (%)**	**I (%)**	**II (%)**	**Total (%)**
Mean ± se	44±25	31±22	67±31	4±2	10±6	10±6	1±0	2±1	3±1
B2. Freshwater and marine water specialists (one species, 1.1% of the total species richness)									
n (%)	11 (0.2)	-	11 (0.2)	2 (0.04)	10 (0.2)	12 (0.2)	-	-	-
B3. Freshwater, brackish water and marine water specialists (12 species, 13.8% of the total species richness)									
n (%)	135 (2.5)	211 (3.8)	346 (6.3)	63 (1.1)	99 (1.8)	162 (3.0)	9 (0.2)	26 (0.5)	35 (0.6)
S (%)	4 (4.6)	6 (6.9)	7 (8.0)	5 (5.7)	5 (5.7)	6 (6.9)	2 (2.3)	2 (2.3)	3 (3.4)
Min.-Max.	1-116	2-168	4-284	4-27	5-38	4-65	4-5	9-17	5-17
Mean ± se	34±27	35±27	49±39	13±4	20±6	27±10	5±1	13±4	12±4
Total tolerant species									
n (%)	849(15.5)	648(11.8)	1,497(27.3)	88(1.6)	148(2.7)	236(4.3)	16(0.3)	34(0.6)	50(0.9)
S (%)	21 (24.1)	20 (23.0)	25 (28.7)	12(13.8)	10(11.5)	13(14.9)	7(8.0)	6 (6.9)	8(9.2)
Min.-Max.	1-409	2-320	4-420	1-27	3-38	1-65	1-5	1-17	1-17
Mean ± se	40±19	32±17	60±23	7±2	15±4	18±6	2±1	6±3	6±2
Global	2,131(38.8)	1,542(28.1)	3,673(66.9)	285(5.2)	462(8.4)	747(13.6)	28(0.5)	57(1.0)	85(1.5)

Environments	Site 4			Pooled sites		
	I (%)	**II (%)**	**Total (%)**	**I (%)**	**II (%)**	**Total (%)**
A. Freshwater specialists (54 species, 62.1% of the total species richness)						
n (%)	440 (8.0)	178 (3.2)	618 (11.3)	1,931 (35.2)	1,409 (25.7)	3,340 (60.9)
S (%)	35 (40.2)	25 (28.7)	37 (42.5)	50 (57.5)	44 (50.6)	54 (62.1)
Min.-Max.	1-89	1-47	1-121	1-331	1-303	1-579
Mean ± se	13±3	7±2	17±4	39±10	32±9	62±16
B. Tolerant species (33 species, 37.9% of the total species richness)						
B1. Freshwater and brackish water specialists (20 species, 23.0% of the total species richness)						
n (%)	82 (1.5)	17 (0.3)	99 (1.8)	815 (14.9)	501 (9.1)	1,316 (24.0)
S (%)	9 (10.3)	4 (4.6)	10 (11.5)	20 (23.0)	16 (18.4)	20 (23.0)
Min.-Max.	1-21	3-8	1-24	1-444	1-320	1-491
Mean ± se	9±3	4±1	10±3	41±22	31±19	66±29
B2. Freshwater and marine water specialists (one species, 1.1% of the total species richness)						
n (%)	8 (0.1)	1 (0.02)	9 (0.2)	21 (0.4)	11 (0.2)	32 (0.6)
B3. Freshwater, brackish water and marine water specialists (12 species, 13.8% of the total species richness)						
n (%)	154 (2.8)	102 (1.9)	256 (4.7)	361 (6.6)	438 (8.0)	799 (14.6)
S (%)	5 (5.7)	5 (5.7)	6 (6.9)	8 (9.2)	11 (12.6)	12 (13.8)
Min.-Max.	2-69	1-64	1-133	1-212	1-287	1-499
Mean ± se	31±11	20±11	43±20	45±25	40±25	67±40
Total tolerant species						
n (%)	244 (4.4)	120 (2.2)	364 (6.6)	1,197 (21.8)	950 (17.3)	2,147 (39.1)
S (%)	16 (18.4)	10 (11.5)	17 (19.5)	29 (33.3)	28 (32.2)	33 (37.9)

Environments	Site 4			Pooled sites		
	I (%)	II (%)	Total (%)	I (%)	II (%)	Total (%)
Min.-Max.	1-69	1-64	1-133	1-444	1-320	1-499
Mean ± se	16±5	12±6	21±8	41±16	34±15	65±22
Global	684 (12.5)	298 (5.4)	982 (17.9)	3,128 (57.0)	2,359 (43.0)	5,487 (100.0)

I: dry season; II: rainy season; Min.: minimum abundance; Max.: maximum abundance; n: sample size; S: species richness; se: standard error. Percentages of th species abundance were calculated on 5487 specimens while percentages of the richness were calculated on 87 species.

Al. guttata, *Al. rustica*, *Bi. intermedia*, *Ch. sphaericus*, *Cryptocyclops* sp., *Daphnia* sp. and *Di. sarsi* were correlated with two species respectively (Table 7A). *Ectocyclops* sp. was correlated with *Ao. excisa*, *Bi. affinis* and *Chydorus piger* respectively (Table 7A). *Ectocyclops* sp. was correlated with nine species (Table 7A). *Mesocyclops* sp. was correlated with four species (Table 7A). The Cyclopidae "Undetermined 3" was correlated with 15 species (Table 7A). As part of group 2, *Abdiacyclops* sp., *Daphnia* sp., *Ku. longirostris*, and *Le. diaphanous* were each correlated with six species (Table 7B). *Ac. aduncus* was correlated with 13 species (Table 7B). *Ac. angustatus*, *Al. protzi* and *Bi. affinis* were each correlated with 20 species (Table 7B). *Ac. harpae* and *Al. natalensis* were each correlated with 16 species (Table 7B). *Afrocyclops* sp. and *Ka. karua* were each correlated with eight species (Table 7B). *Al. guttata* was correlated with 24 species (Table 7B). *Ao. excisa* and *Al. quadrangularis* were each correlated with 23 species (Table 7B). *Al. rustica* was correlated with 21 species (Table 7B). *Allocyclops* sp., *Diaptomus* sp. and *Mi. macleayi* were each correlated with four species (Table 7B). *Bi. intermedia* and *Di. brachyurum* were each correlated with 19 species (Table 7B). *By. longimanus* was correlated with 17 species (Table 7B). *Ca. rectirostris*, *Dr. dentata* and the Cyclopidae "Undetermined 3" were each correlated with 11 species (Table 7B). *Ce. megops*, *Da. curvirostris* and *Eu. orientalis* were each correlated with 10 species (Table 7B). *Ch. gibbus* and *Ch. piger* were each correlated with 14 species (Table 7B). *Ch. sphaericus* was correlated with 29 species (Table 7B). *Cryptocyclops* sp., *Ku. latissima* and *Pseudodiaptomus* sp. were each correlated with seven species (Table 7B). *Da. lumholtzi* was correlated with nine species (Table 7B). *Da. obtusa*, *Harpacticella* sp. and *O. singalensis* were each correlated with two species (Table 7B). *Di. sarsi* was correlated with 12 species (Table 7B).

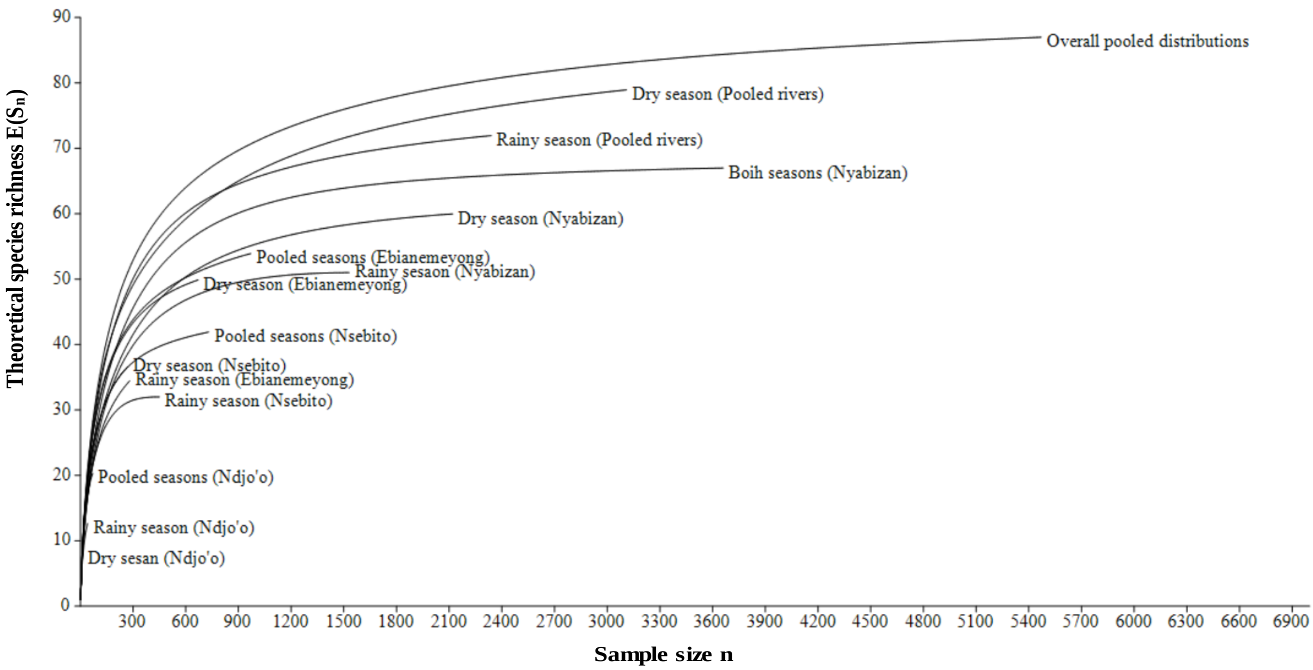

Figure 2. *Individual rarefaction curves of the aquatic micro-arthropods in the studied rivers.*

Microcyclops sp. was correlated with *Paradiaptomus* sp., and *Pl. denticulatus* was correlated with *Pl. laevis* (Table 7B). Water temperature was negatively correlated with *Ac. harpae* (r_{bis}=-0.313, p=0.030).

3.4.2. Species and Physico-Chemical Parameters

Between species and physicochemical parameters, the water temperature was negatively correlated with *Acroperus harpae* ($r_{.bis}$=-0.313, p=0.030), *Afrolaophonte* sp. ($r_{.bis}$=-0.395, p=5.5x10^{-3}), *Paradiaptomus* sp. ($r_{.bis}$=-0.395, p=5.5x10^{-3}). It was the same between temperature and *R. falcata* ($r_{.bis}$=-0.313, p=0.030). Temperature was positively correlated with *Ac. aduncus* ($r_{.bis}$=+0.299, p=0.039). pH was correlated with *Ac. aduncus* ($r_{.bis}$=-0.343, p=0.017). Color was correlated with eight species: *Ac. harpae* ($r_{.bis}$=+0.444, p=0.002), *Afrolaophonte* sp. ($r_{.bis}$=+0.345, p=0.016), *Allocyclops* sp. ($r_{.bis}$=+0.295, p=0.042), *Al. natalensis* ($r_{.bis}$=+0.407, p=0.004), *Ch. ovalis* ($r_{.bis}$=+0.304, p=0.036), *Paradiaptomus* sp. ($r_{.bis}$=+0.345, p=0.016), *Pl. striatus* ($r_{.bis}$=+0.319, p=0.027), and *R. falcata* ($r_{.bis}$=+0.444, p=1.6x10^{-3})). BOD_5 was correlated with *Ac. harpae* ($r_{.bis}$=+0.391, p=0.006), *Allocyclops* sp. ($r_{.bis}$=+0.361, p=0.012). It was the same between BOD_5 and *Al. natalensis* ($r_{.bis}$=+0.453, p=0.001), *Bi. affinis* ($r_{.bis}$=+0.311, p=0.032), *Ch. piger* ($r_{.bis}$=+0.320, p=0.027), *Ku. latissima* ($r_{.bis}$=+0.320, p=0.027), *Pl. striatus* ($r_{.bis}$=+0.295, p=0.042), *R. falcata* ($r_{.bis}$=+0.391, p=6.1x10^{-3}). SS was correlated with 15 species: *Al. quadrangularis* ($r_{.bis}$=+0.321, p=0.026), *Di. brachyurum* ($r_{.bis}$=+0.327, p=0.027), *Ch. gibbus* ($r_{.bis}$=+0.291, p=0.044). The following species correlated with SS were *Dr. dentata* ($r_{.bis}$=+0.291, p=0.044), *I. agilis* ($r_{.bis}$=+0.291, p=0.044), *Ka. karua* ($r_{.bis}$=+0.368, p=0.01), *Ly. acanthocercoides* ($r_{.bis}$=+0.368, p=0.010), *Mo. macrocopa* ($r_{.bis}$=+0.300, p=0.038), *Mi. macleayi* ($r_{.bis}$=+0.327, p=0.023), *Neocyclops* sp. ($r_{.bis}$=+0.304, p=0.036), *Po. pediculus* ($r_{.bis}$=+0.354, p=0.013), *Sc. kingi* ($r_{.bis}$=+0.327, p=0.023), *Se. calanoides* ($r_{.bis}$=+0.327, p=0.023), *Sm. exspinosus* ($r_{.bis}$=+0.291, p=0.044), *Sm. vetulus* ($r_{.bis}$=+0.368, p=0.010), and *Sr. serricaudatus* ($r_{.bis}$=+0.305, p=0.035)). Conductivity was correlated with *Di. brachyurum* ($r_{.bis}$=-0.343, p=0.017), *Ka. karua* ($r_{.bis}$=-0.361, p=0.012), *Ly. acanthocercoides* ($r_{.bis}$=-0.361, p=0.012), *Mi. macleayi* ($r_{.bis}$=-0.343, p=0.017), *Po. pediculus* ($r_{.bis}$=-0.336, p=0.019), *Sc. kingi* ($r_{.bis}$=+0.343, p=0.017), *Se. calanoides* ($r_{.bis}$=-0.343, p=0.017), and *Sm. vetulus* ($r_{.bis}$=-0.361, p=0.012). *Ectocyclops* sp. and *Mo. macrocopa* were each correlated with five species (Table 7B).

Table 4. *Matrix of the species richness, diversity, evenness and dominance indices.*

	A. Site 1 (dam)			B. Site 2			C. Site 3		
	I	II	Total	I	II	Total	I	II	Total
n (%)	2131 (38.8)	1542 (28.1)	3673 (66.9)	285	462	747	28 (0.5)	57 (1.0)	85 (1.5)
S (%)	60 (69.0)	51 (58.6)	67 (77.0)	37 (42.5)	32 (36.8)	42 (48.3)	14 (16.1)	14 (16.1)	21 (24.1)
n_{max} (%)	409 (7.5)	320 (5.8)	420 (7.7)	29 (0.5)	96 (13.7)	119 (2.2)	5 (0.09)	17 (0.3)	17 (0.3)
Mg	7.698	6.811	8.040	6.369	5.053	6.197	3.901	3.215	4.502
d=S/n	0.028	0.033	0.018	0.130	0.069	0.056	0.500	0.246	0.247
Chao1	61	51	67	40	32	44	18	16	21
SE (%)	98.4	100.0	100.0	93.4	100.0	95.5	76.9	87.5	98.2
$E(S_{n=11})$	8±1	7±1	8±1	9±1	8±1	8±1	8±1	7±1	8±1
H' (bits)	3.042	2.903	3.193	3.139	2.862	3.107	2.451	2.241	2.703
H'_{max} (bits)	4.094	3.932	4.205	3.611	3.466	3.738	2.639	2.639	3.045
D	0.082	0.096	0.065	0.056	0.089	0.067	0.102	0.147	0.092
N_1	20.952	18.233	24.348	23.077	17.494	22.361	11.596	9.407	14.918
N_2	12.268	10.434	15.456	17.816	11.199	15.029	9.804	6.784	10.832
N_2/N_1	0.586	0.572	0.635	0.772	0.640	0.672	0.845	0.721	0.726
J	0.743	0.738	0.759	0.869	0.826	0.831	0.929	0.849	0.888
I_{BP}	0.192	0.208	0.114	0.102	0.208	0.159	0.179	0.298	0.200

	D. Site 4			Dry season *vs.* rainy season: Student t-test		
	I	II	Total	Sites	Shannon H'	Simpson D
n (%)	684 (12.5)	298 (5.4)	982 (17.9)	Dam	t=3.21; df=3256.4; p=0.001	t=-3.08; df=3098.8; p=0.002 *

	D. Site 4			**Dry season *vs.* rainy season: Student t-test**		
	I	**II**	**Total**	**Sites**	**Shannon H'**	**Simpson D**
S (%)	50 (57.5)	35 (40.2)	54 (62.1)	Site 2	t=3.82; df=689.63; $p=1.4x10^{-4}$ *	t=-4.26; df=695.81; $p=2.2x10^{-5}$ *
n_{max} (%)	89 (1.6)	64 (1.2)	133 (2.4)	Site 3	t=1.09; df=65.77; p=0.280 ns	t=-1.17; df=81.41; p=0.244 ns
Mg	7.506	5.968	7.693	Site 4	t=5.31; df=530.5; $p=1.6x10^{-7}$ *	t=-3.85; df=386.2; $p=1.4x10^{-4}$ *
d=S/n	0.073	0.117	0.055	Comparison of the Shannon-Weaver index H' between rivers: Student t-test		
Chao1	52	47	58		Dry season	Rainy season
SE (%)	95.9	74.5	93.9	A *vs.* B	t=-1.635; df=459.30; p=0.103 ns	t=0.686; df=910.12; p=0.493 ns
$E(S_{n=11})$	8 ±1	8 ±1	8 ±1	A *vs.* C	t=3.958; df=29.996; $p=4.3x10^{-4}$ *	t=5.150; df=65.57; $p=2.6x10^{-6}$ *
H' (bits)	3.234	2.814	3.227	A *vs.* D	t=-3.860; df=1340.70; $p=1.2x10^{-4}$ *	t=1.188; df=456.86; p=0.235 ns
H'_{max} (bits)	3.912	3.555	3.989	B *vs.* C	t=-4.413; df=35.51; $p=9.1x10^{-5}$ *	t=-4.636; df=76.87; $p=1.4x10^{-5}$ *
D	0.060	0.097	0.063	B *vs.* D	t=1.422; df=645.73; p=0.156 ns	t=-0.573; df=599.89; p=0.567 ns

Table 4. *Continued.*

	D. Site 4			**Dry season *vs.* rainy season: Student t-test**		
	I	**II**	**Total**	**Sites**	**Shannon H'**	**Simpson D**
N_1	25.370	16.671	25.213	C *vs.* D	t=-5.132; df=32.69; $p=1.3x10^{-5}$ *	t=-4.052; df=94.11; $p=1.0x10^{-4}$ *
N_2	16.633	10.269	15.760		Pooled seasons	
N_2/N_1	0.656	0.616	0.625	A *vs.* B	t=1.99; df=1216.10; p=0.050 ns	
J	0.827	0.791	0.809	A *vs.* C	t=4.879; df=92.30; $p=4.4x10^{-6}$ *	
I_{BP}	0.130	0.215	0.135	A *vs.* D	t=-0.838; df=1642.30; p=0.402 ns	
				B *vs.* C	t=-3.842; df=111.51; $p=2.0x10^{-4}$ *	
				B *vs.* D	t=2.293; df=1676.8; p=0.022 *	
				C *vs.* D	t=-5.005; df=109.48; $p=2.2x10^{-6}$ *	

I: dry season; II: rainy season; Chao1: abundance based non parametric species richness estimator; d: species richness ratio; H': Shannon-Weaver; H'_{max}: maximum Shannon-Weaver; D: Simpson's diversity; Mg: Margalef index; n: sample size; N_1: Hill's first order diversity number; N_2: Hill's second order diversity number; n_{max}: maximum abundance; N_2/N_1: Hill's ratio; J: Pielou evenness index; I_{BP}: Berger-Parker index. S: species richness; SE: sampling effort; $E(S_{n=11})$: theoretical richness for a standard sample of 11 specimens; ns: not significant (p≥0.05); *: significant (p<0.05).

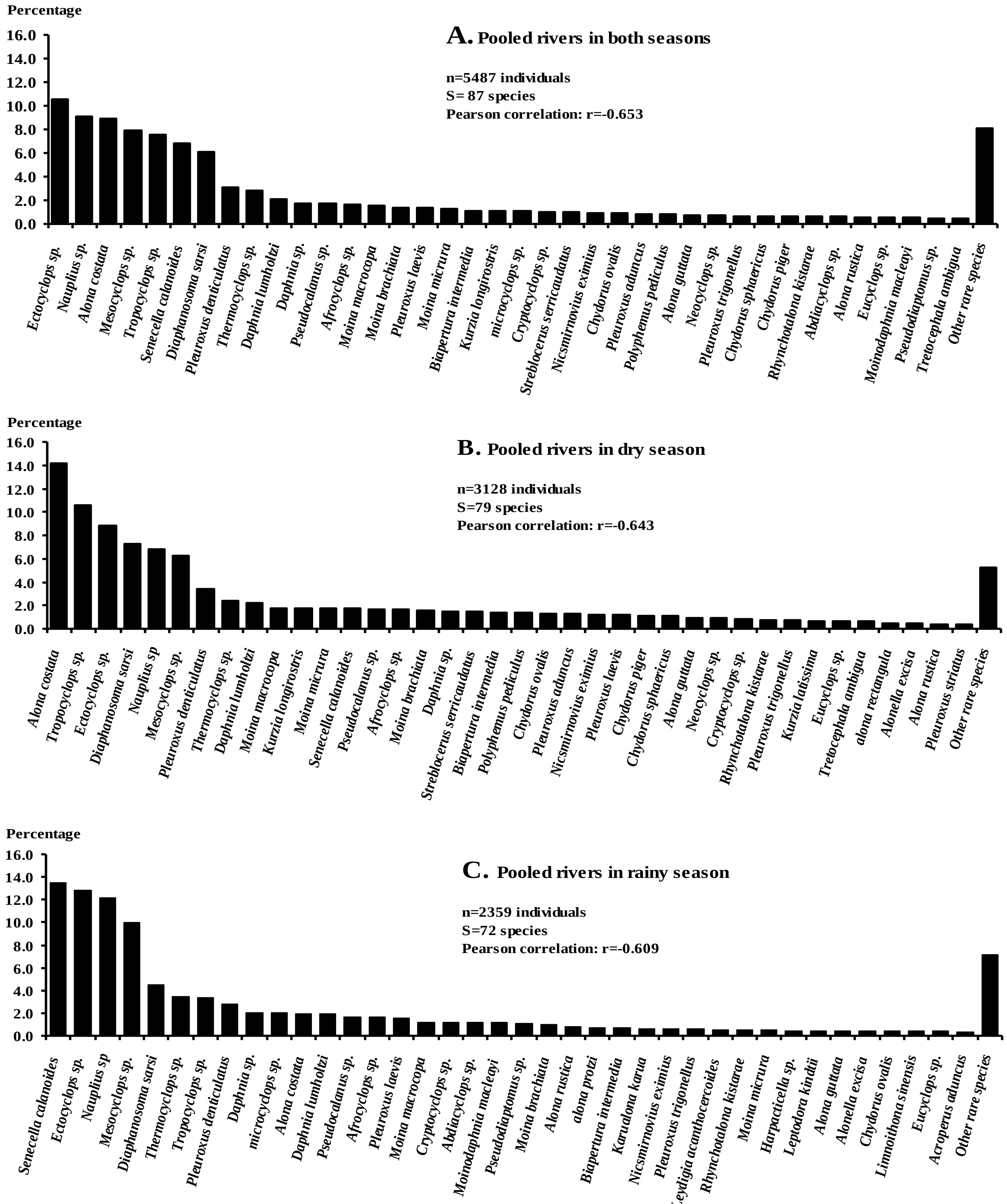

Figure 3. *Rank-frequency diagrams of the pooled collected aquatic arthropods in four rivers during two seasons, showing species in decreasing order of numerical occurrence. Lists of other rare species are presented in Table 2.*

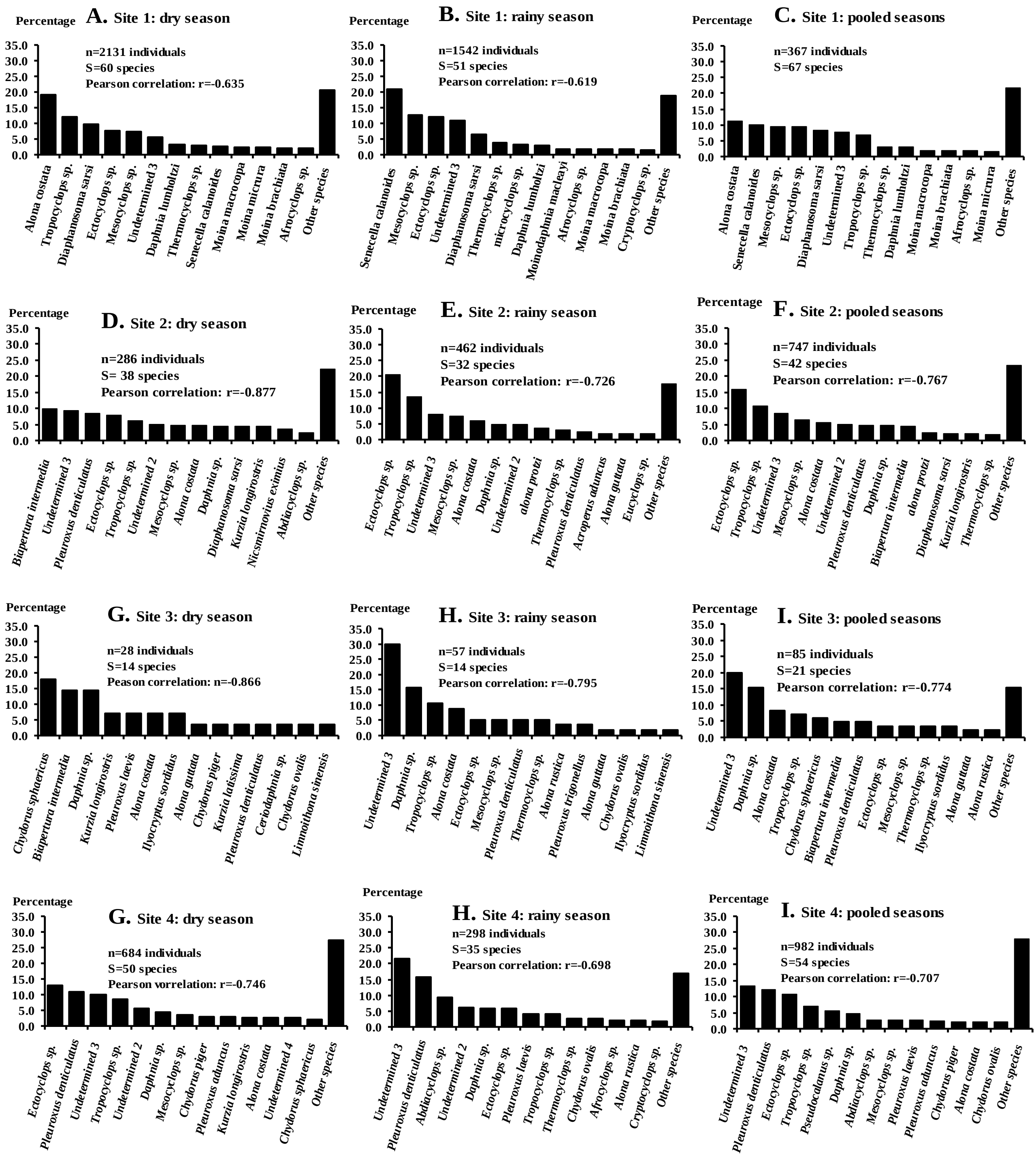

Figure 4. *Rank-frequency diagrams of the aquatic arthropods species abundance distributions (SADs) in four rivers, showing species in decreasing order of numerical occurrence. Lists of other rare species are presented in the text.*

Table 5. *Matrix of the Bray-Curtis dissimilarity index between species assemblages recorded in four rivers.*

		Site 1 (dam)			Site 2			Site 3			Site 4		
		I	II	III	I	II	III	I	II	III	I	II	III
Site 1	I	1.000											
	II	0.578	1.000										

		Site 1 (dam)			Site 2			Site 3			Site 4		
		I	II	III	I	II	III	I	II	III	I	II	III
	III	0.716	0.614	1.000									
Site 2	I	0.224	0.258	0.201	1.000								
	II	0.241	0.210	0.204	0.305	1.000							
	III	0.313	0.299	0.307	0.649	0.683	1.000						
Site 3	I	0.098	0.066	0.056	0.243	0.091	0.286	1.000					
	II	0.028	0.023	0.016	0.127	0.085	0.195	0.143	1.000				
	III	0.123	0.087	0.070	0.127	0.045	0.166	0.880	0.353	1.000			
Site 4	I	0.378	0.238	0.258	0.290	0.305	0.280	0.151	0.071	0.208	1.000		
	II	0.134	0.151	0.091	0.267	0.195	0.254	0.030	0.069	0.087	0.365	1.000	
	III	0.387	0.267	0.296	0.300	0.258	0.366	0.095	0.043	0.132	0.749	0.573	1.000

I: Dry season; II: Rainy season; III: pooled seasons

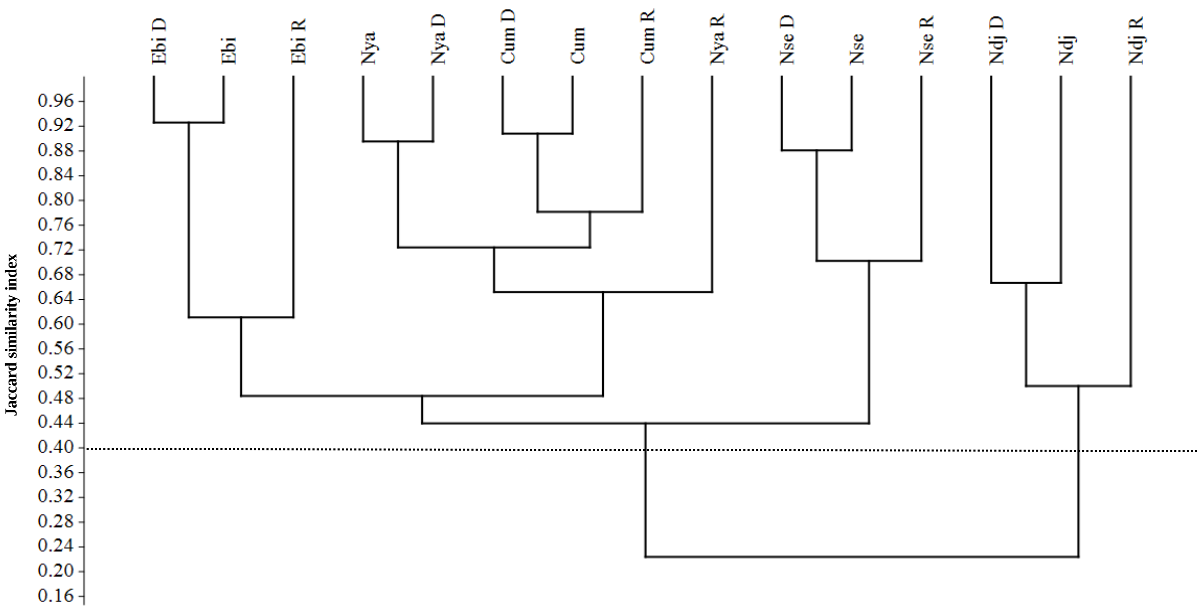

Figure 5. *Hierarchical Cluster Analysis based on Jaccard's index using the "Unweighted Pair Group Method with Arithmetic mean" (UPGMA) algorithm and showing similarity in aquatic micro-arthropd assemblages among four sites (Cophenetic correlation: 0.94). Ebi D: Ebianemeyong river in dry season (Site 4); Ebi R: Enianemeyong river in rainy season (Site 4); Ebi: pooled seasons in Ebianemeyong river (Site 4); Nya D: Nyabizan river in dry season (dam); Nya R: Nyabizan river in rainy season (dam); Nya: pooled seasons in Nyabizan river (dam); Ndj D: Ndjo'o river in dry season (Site 3); Ndj R: Ndjo'o river in rainy season (Site 3); Ndj: pooled seasons (Site 3); Nse D: Nsebito river in dry season (Site 2); Nse R: Nsebito river in rainy season (Site 2); Nse: pooled seasons in Nsebito river (Site 2); Cum D: Pooled rivers in dry season; Cum R: Pooled rivers in rainy season; Cum: pooled seasons in pooled rivers.*

Table 6. *Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC) values for the adjusted models.*

	A. Dam: AIC (BIC)			B. Site 2: AIC (BIC)		
	Dry season	Rainy season	Pooled seasons	Dry season	Rainy season	Pooled seasons
Broken-Stick (BS)	1175.1 (1175.1)	915.9 (915.9)	1913.4 (1913.4)	144.1 (144.1)	188.1 (188.1)	238.8238.8)
Log-Linear (LL)	579.4 (581.5)	572.2 (574.1)	884.1 (886.3)	135.2 (136.9)*	177.7 (179.2)	215.3 (217.0)

	A. Dam: AIC (BIC)			B. Site 2: AIC (BIC)		
	Dry season	Rainy season	Pooled seasons	Dry season	Rainy season	Pooled seasons
Log-Normal (LN)	347.2 (351.4)	342.8 (346.7)	907.1 (911.5)	152.0 (155.3)	144.3 (147.3)	187.5 (191.0)*
Zipf (Z)	512.6 (516.8)	387.8 (391.6)	1313.8 (1318.2)	181.0 (184.3)	146.9 (149.9)	244.9 (248.4)
Zidf-Mandelbrot (ZM)	300.5 (306.8)*	278.0 (283.8)*	527.3 (534.0)*	138.6 (143.5)	136.9 (141.3)*	191.1 (196.3)

	C. Site 3: AIC (BIC)			D. Site 4: AIC (BIC)		
Broken-Stick (BS)	39.3 (39.3)	44.8 (44.8)*	70.6 (70.6)	278.0 (278.0)	175.6 (175.6)	396.4 (396.4)
Log-Linear (LL)	38.1 (38.7)*	47.0 (47.7)	72.3 (73.4)	241.0 (242.9)	154.7 (156.2)	321.1 (323.1)
Log-Normal (LN)	39.8 (41.1)	46.5 (47.8)	69.7 (71.8)	217.7 (221.6)	129.1 (132.2)	258.1 (262.1)
Zipf (Z)	39.6 (40.9)	46.2 (47.5)	68.6 (70.7)*	269.9 (273.7)	136.3 (139.4)	332.4 (336.4)
Zidf-Mandelbrot (ZM)	41.2 (43.2)	48.0 (50.0)	70.2 (73.4)	207.8 (213.5)*	126.6 (131.3)*	249.8 (255.8)

I: Dry season; II: Rainy season; III: pooled seasons; *: best fitted model. Best fitted models are in bold.

Mesocyclops sp. and *Ni. eximius* were each correlated with three species (Table 7B). It was correlated with *Da. obtusa* ($r_{.bis}$=+0.295, p=0.042), the Calanoida "Undetermined 2" ($r_{.bis}$=+0.375, p=8.6x10^{-3}), and *St. major* ($r_{.bis}$=+0.316, p=0.029). The water turbidity was correlated with *Al. protzi* ($r_{.bis}$=-0.312, p=0.031). NH_4^+ was correlated with *Ceriodaphnia* sp. ($r_{.bis}$=+0.302, p=0.037). PO_4^{3-} was correlated with *Ceriodaphnia* sp. ($r_{.bis}$=+0.361, p=0.012), and *Ly. quadrangularis* ($r_{.bis}$=+0.317, p=0.028).

4. Discussion

4.1. Physicochemical Parameters

Memwe'ele dam, the tributary river and the adjacent river are warm. BOD_5, conductivity, NO_2^-, NO_3^-, pH, PO_4^{3-}, temperature and SS were on average within the WHO standards for drinking water [17]. Chl. a, color, DO, NH_4^+ and turbidity were on average above the WHO standard upper limit for drinking water [17]. Based on WQI values, raw waters were unfit for direct drinking, in accordance with the guide [27-29], but they presented ideal conditions for fish farming and irrigation for agriculture. It is known that Temperature has a positive effect on the biodiversity and controls the growth rate of living organisms, the optimum being 25-32.5 ℃ [30]. The minimum requirements for the aquatic live are the penetration of light and the DO. Temperatures were around the optimal limit of standards and therefore provided optimal conditions for aquatic organisms. It is well known that many species are acidophilic while several others are basophilic. But pH higher than 9 or lower than 6 are known to inhibit the photosynthesis and to affect the health of micro-organisms. Extreme values were not recorded. SS exceeded standards for drinking water (0 mg.l^{-1}) [17] but was within the standards for fish farming (10-20 mg.l^{-1}) [31, 32].NO_2^-, NH_4^+ and PO_4^{3-} and the high water color, suggested that waters contained sufficient mineral nutrients for microorganisms [33]. Moreover, waters in the study sites presented high values of chlorophyll a than the norm, suggesting a high level of photosynthesis [17, 32].

Table 7. *Values of the significant Kendall's tau correlation coefficient between the micro-arthropods in 48 sample units from the collection sites (12 sample units respectively).*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
A. Negative correlations					
Afrocyclops sp.		*Cryptocyclops* sp.		*Mesocyclops* sp.	
Alona rustica	-0.210(0.035)*	*Pl. denticulatus*	-0.206(0.039)*	*Nicsmirnovius eximius*	-0.249(0.013)*
Daphnia sp.	-0.221(0.027)*	*Daphnia* sp.		*Pleuroxus denticulatus*	-0.276(0.006)*
Nicsmirnovius eximius	-0.199(0.047)*	*Ectocyclops* sp.	-0.289(0.004)*	*Pl. laevis*	-0.262(0.009)*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Pleuroxus denticulatus	-0.221(0.027)*	*Mesocyclops* sp.	-0.276(0.006)*	Undetermined 3	
Pleuroxus laevis	-0.209(0.036)*	*Diaphanosoma sarsi*		*Alona guttata*	-0.271(0.007)*
Alona guttata		*Ectocyclops* sp.	-0.259(0.009)*	*Alona rustica*	-0.287(0.004)*
Ectocyclops sp.	-0.260(0.009)*	*Mesocyclops* sp.	-0.247(0.013)*	*Alonella excisa*	-0.216(0.030)*
Mesocyclops sp.	-0.248(0.013)*	*Ectocyclops* sp.		*Biapertura affinis*	-0.217(0.030)*
Alona rustica		*Alonella excisa*	-0.207(0.038)*	*Biapertura intermedia*	-0.271(0.006)*
Ectocyclops sp.	-0.275(0.006)*	*Biapertura affinis*	-0.208(0.037)*	*Chydorus piger*	-0.216(0.030)*
Mesocyclops sp.	-0.263(0.008)*	*Chydorus piger*	-0.207(0.038)*	*Chydorus sphaericus*	-0.271(0.006)*
Biapertura intermedia		*Kurzia latissima*	-0.207(0.038)*	*Daphnia* sp.	-0.302(0.002)*
Ectocyclops sp.	-0.260(0.009)*	*Kurzia longirostris*	-0.259(0.009)*	*Diaphanosoma sarsi*	-0.270(0.007)*
Mesocyclops sp.	-0.249(0.013)*	*Moina macrocopa*	-0.207(0.038)*	*Kurzia latissima*	-0.216(0.030)*
Chydorus sphaericus		*Ni. eximius*	-0.260(0.009)*	*Kurzia longirostris*	-0.270(0.007)*
Ectocyclops sp.	-0.260(0.009)*	*Pl. denticulatus*	-0.289(0.004)*	*Moina macrocopa*	-0.216(0.030)*
Mesocyclops sp.	-0.249(0.013)*	*Pl. laevis*	-0.274(0.006)*	*Nicsmirnovius eximius*	-0.271(0.006)*
Cryptocyclops sp.		*Mesocyclops* sp.		*Pleuroxus denticulatus*	-0.302(0.003)*
Daphnia sp.	-0.206(0.039)*	*Kurzia longirostris*	-0.247(0.013)*	*Pl. laevis*	-0.286(0.004)*
B. Positive correlations					
Abdiacyclops sp.		*Acroperus harpae*		*Alona natalensis*	
Allocyclops sp.	0.473(2x10^{-6})*	*Ch. piger*	0.531(1x10^{-7})*	*Ao. excisa*	0.382(1x10^{-4})*
Cryptocyclops sp.	0.487(1x10^{-6})*	*Ch. sphaericus*	0.203(0.042)*	*Bi. affinis*	0.647(9x10^{-11})*
Ectocyclops sp.	0.310(0.002)*	*Daphnia* sp.	0.423(2x10^{-5})*	*Ca. rectirostris*	0.210(0.036)*
Mesocyclops sp.	0.316(0.002)*	*Di. sarsi*	0.351(4x10^{-4})*	*Ce. megops*	0.548(4x10^{-8})*
Microcyclops sp.	0.210(0.035)*	Ku. latissima	0.531(1x10^{-7})*	Ch. piger	0.671(2x10^{-11})*

Table 7. Continued.

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
B. Positive correlations (Continued)					
Abdiacyclops sp. (continued)		*Acroperus harpae* (continued)		*Alona natalensis* (continued)	
Paradiaptomus sp.	0.711(1x10^{-12})*	*Le. diaphanus*	0.272(0.006)*	*Da. obtusa*	0.354(4x10^{-4})*
Acroperus aduncus		*Moina macrocopa*	0.217(0.029)*	*Daphnia* sp.	0.522(2x10-7)*
Alona guttata	0.301(003)*	*Ni. eximius*	0.374(2x10^{-4})*	*Di. sarsi*	0.432(2x10-5)*
Alona protzi	0.483(1x10^{-6})*	*Ox. singalensis*	0.392(9x10^{-5})*	*Ku. latissima*	0.639(2x10^{-10})*
Alona rustica	0.324(0.001)*	*Pl. denticulatus*	0.447(7x10^{-6})*	*Ku. longirostris*	0.310(0.002)*
Bi. intermedia	0.555(3x10^{-8})*	*Pl. laevis*	0.446(8x10^{-6})*	*Mo. macrocopa*	0.382(1x10^{-4})*
Ca. rectirostris	0.532(1x10^{-7})*	*Afrocyclops* sp.		*Ni. eximius*	0.465(3x10^{-6})*
Ch. sphaericus	0.266(0.008)*	*Allocyclops* sp.	0.435(1x10^{-5})*	*Ox. singalensis*	0.292(0.003)*
Daphnia sp.	0.481(1x10^{-6})*	*Cryptocyclops* sp.	0.554(3x10^{-8})*	*Pl. denticulatus*	0.542(6x10^{-8})*

Species 1/species 2	**τ (p-value)**	**Species 1/species 2**	**τ (p-value)**	**Species1/species 2**	**τ (p-value)**
Di. sarsi	0.287(0.004)*	*Diaptomus* sp.	0.518(2x10^{-7})*	*Pl. laevis*	0.511(3x10^{-7})*
Eu. orientalis	0.210(0.035)*	*Ectocyclops* sp.	0.744(9x10^{-14})*	*Alona quadrangularis*	
Ku. longirostris	0.539(7x10^{-8})*	*Harpacticella* sp.	0.588(4x10^{-9})*	*Ch. sphaericus*	0.455(4x10^{-6})*
Ni. eximius	0.498(6x10^{-7})*	*Mesocyclops* sp.	0.755(4x10^{-14})*	*Di. brachyurum*	0.356(4x10^{-4})*
Pl. denticulatus	0.456(5x10^{-6})*	*Microcyclops* sp.	0.798(1x10^{-15})*	*Ac. angustatus*	0.700(2x10^{-12})*
Pl. laevis	0.410(4x10^{-5})*	*Paradiaptomus* sp.	0.322(0.001)*	*Al. guttata*	0.485(1x10^{-6})*
Acroperus angustatus		*Alona guttata*		*Al. protzi*	0.585(5x10^{-9})*
Al. guttata	0.351(4x10-4)*	*Al. natalensis*	0.297(0.003)*	*Ao. excisa*	0.524(2x10^{-7})*
Al. protzi	0.439(1x10-5)*	*Al. protzi*	0.711(1x10^{-12})*	*Bi. affinis*	0.539(7x10^{-8})*
Ao. excisa	0.331(0.001)*	*Al. rustica*	0.622(4x10^{-10})*	*Bi. intermedia*	0.406(5x10^{-5})*
Bi. affinis	0.341(0.001)*	*Ao. excisa*	0.461(4x10^{-6})*	*Ch. gibbus*	0.700(2x10^{-12})*
Bi. intermedia	0.284(0.004)*	*Bi. affinis*	0.469(3x10^{-6})*	*Ch. piger*	0.537(7x10^{-8})*
Chydorus gibbus	1.000(1x10^{-23})*	*Bi. intermedia*	0.428(2x10^{-5})*	*Da. lumholtzi*	0.391(9x10^{-5})*
Chydorus piger	0.367(2x10^{-4})*	*Ca. rectirostris*	0.411(4x10^{-5})*	*Di. sarsi*	0.479(2x10^{-6})*
Di. sarsi	0.350(5x10^{-4})*	*Ce. megops*	0.284(0.004)*	*Dr. dentata*	0.700(2x10^{-12})*
Dr. dentata	1.000(1x10^{-23})*	*Ch. gibbus*	0.351(4x10^{-4})*	*Eu. orientalis*	0.670(2x10^{-11})*
Eu. orientalis	0.469(3x10^{-6})	*Ch. piger*	0.615(7x10^{-10})*	*Ka. karua*	0.649(8x10^{-11})*
Karualona karua	0.465(3x10^{-6})	*Da. obtusa*	0.403(5x10^{-5})*	*Ku. latissima*	0.575(8x10^{-9})*
Kurzia latissima	0.420(3x10^{-5})	*Daphnia* sp.	0.485(1x10^{-6})*	*Ku. longirostris*	0.426(2x10^{-5})*
Kurzia longirostris	0.246(0.014)*	*Di. sarsi*	0.587(4x10^{-9})*	*Le. diaphanus*	0.559(2x10^{-8})*
Le. diaphanus	0.391(9x10^{-5})*	*Dr. dentata*	0.351(4x10^{-4})*	*Mo. macrocopa*	0.575(8x10^{-9})*
Mo. macrocopa	0.385(1x10^{-4})*	*Eu. orientalis*	0.428(2x10^{-5})*	*Mi. macleayi*	0.355(4x10^{-4})*
Mi. macleayi	0.534(9x10^{-8})*	*Ka. karua*	0.265(0.008)*	*Ni. eximius*	0.455(5x10^{-6})*
Ni. eximius	0.352(4x10^{-4})*	*Ku. latissima*	0.646(9x10^{-11})*	*Ox. singalensis*	0.784(4x10^{-15})*
Ox. singalensis	0.548(4x10^{-8})*	Ku longirostris	0.695(3x10^{-12})*	Pl. laevis	0.406(5x10^{-5})*

***Table 7**. Continued.*

Species 1/species 2	**τ (p-value)**	**Species 1/species 2**	**τ (p-value)**	**Species1/species 2**	**τ (p-value)**
B. Positive correlations (Continued)					
Acroperus angustatus (continued)		*Alona guttata* (continued)		*Alona protzi* (continued)	
Pl. denticulatus	0.245(0.014)*	*Le. diaphanus*	0.507(4x10^{-7})*	*Al. rustica*	0.503(5x10^{-7})*
Pl. laevis	0.277(0.006)*	*Mo. macrocopa*	0.326(0.001)*	*Ao. excisa*	0.250(0.012)*
Acroperus harpae		*Ni. eximius*	0.593(3x10^{-9})*	*Bi. affinis*	0.259(0.009)*
Al. natalensis	0.811(4x10^{-16})*	*Ox. singalensis*	0.568(1x10^{-8})*	*Bi. intermedia*	0.521(2x10^{-7})*
Al. rustica	0.418(3x10^{-5})*	*Pl. denticulatus*	0.673(2x10^{-11})*	*Ca. rectirostris*	0.392(8x10^{-5})*
Ao. excisa	0.230(0.021)*	*Pl. laevis*	0.629(3x10^{-10})*	*Ch. gibbus*	0.439(1x10^{-5})*
Biapertura affinis	0.539(7x10^{-8})*	*Alona natalensis*		*Ch. piger*	0.258(0.010)*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Ca. rectirostris	0.294(0.003)*	*Al. rustica*	0.476(2x10-6)*		
Alona protzi		*Biapertura affinis*		*Ceriodaphnia megops*	
Da. obtusa	0.263(0.008)*	*Da. obtusa*	0.198(0.047)*	*Ku. latissima*	0.367(2x10^{-4})*
Di. sarsi	0.532(1x10^{-7})*	*Daphnia* sp.	0.267(0.007)*	*Ku. longirostris*	0.335(0.001)*
Dr. dentata	0.439(1x10^{-5})*	*Di. sarsi*	0.741(1x10^{-13})*	*Mo. macrocopa*	0.331(0.001)*
Eu. orientalis	0.589(4x10^{-9})*	*Dr. dentata*	0.341(0.001)*	*Ni. eximius*	0.284(0.004)*
Ka. karua	0.352(4x10^{-4})*	*Eu. orientalis*	0.322(0.001)*	*Pl. denticulatus*	0.292(0.003)*
Ku. latissima	0.291(0.004)*	*Ka. karua*	0.561(2x10^{-8})*	*Pl. laevis*	0.241(0.016)*
Ku. longirostris	0.511(3x10^{-7})*	*Ku. latissima*	0.762(2x10^{-14})*	*Chydorus gibbus*	
Le. diaphanus	0.497(6x10^{-7})*	*Ku. longirostris*	0.449(7x10^{-6})*	*Ch. piger*	0.367(2x10^{-4})*
Mo. macrocopa	0.283(0.005)*	*Le. diaphanus*	0.449(7x10^{-6})*	*Di. sarsi*	0.350(5x10^{-4})*
Ni. eximius	0.507(4x10^{-7})*	*Mo. macrocopa*	0.800(1x10^{-15})*	*Dr. dentata*	1.000(1x10^{-23})*
Ox. singalensis	0.440(1x10^{-5})*	*Mi. macleayi*	0.414(3x10^{-5})*	*Eu. orientalis*	0.469(3x10^{-6})*
Pl. denticulatus	0.433(1x10^{-5})*	*Ni. eximius*	0.559(2x10^{-8})*	*Ka. karua*	0.465(3x10^{-6})*
Pl. laevis	0.448(7x10^{-6})*	*Ox. singalensis*	0.663(3x10^{-11})*	*Ku. latissima*	0.420(3x10^{-5})*
Alona rustica		*Pl. denticulatus*	0.416(3x10^{-5})*	*Ku. longirostris*	0.246(0.014)*
Ao. excisa	0.413(3x10^{-5})*	*Pl. laevis*	0.575(8x10^{-9})*	*Le. diaphanus*	0.391(9x10^{-5})*
Bi. affinis	0.409(4x10^{-5})*	*Biapertura intermedia*		*Mo. macrocopa*	0.385(1x10^{-4})*
Bi. intermedia	0.318(0.001)*	*Ca. rectirostris*	0.458(5x10^{-6})*	*Mi. macleayi*	0.534(9x10^{-8})*
Ca. rectirostris	0.603(2x10^{-9})*	*Ch. gibbus*	0.284(0.004)*	*Ni. eximius*	0.352(4x10^{-4})*
Ce. megops	0.214(0.032)*	*Ch. piger*	0.248(0.013)*	*Ox. singalensis*	0.548(4x10^{-8})*
Ch. piger	0.395(7x10^{-5})*	*Da. curvirostris*	0.322(0.001)*	*Pl. denticulatus*	0.245(0.014)*
Da. curvirostris	0.292(0.003)*	*Da. lumholtzi*	0.511(3x10^{-7})*	*Pl. laevis*	0.277(0.006)*
Da. lumholtzi	0.299(0.003)*	*Daphnia* sp.	0.335(0.001)*	*Chydorus piger*	
Da. obtusa	0.339(0.001)*	*Di. sarsi*	0.597(2x10^{-9})*	*Da. obtusa*	0.254(0.011)*
Daphnia sp.	0.579(6x10^{-9})*	*Dr. dentata*	0.284(0.004)*	*Daphnia* sp.	0.392(9x10^{-5})*
Di. sarsi	0.621(5x10^{-10})*	*Eu. orientalis*	0.640(1x10^{-10})*	*Di. sarsi*	0.566(1x10^{-8})*

Table 7. *Continued.*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
B. Positive correlations (Continued)					
Alona rustica (Continued)		*Biapertura intermedia* (Continued)		*Chydorus piger* (Continued)	
Eu. orientalis	0.416(3x10^{-5})*	*Ka. karua*	0.601(2x10^{-9})*	*Dr. dentata*	0.367(2x10^{-4})*
Ka. karua	0.217(0.029)*	*Ku. latissima*	0.267(0.007)*	*Eu. orientalis*	0.321(0.001)*
Ku. latissima	0.389(1x10^{-4})*	*Ku. longirostris*	0.668(2x10^{-11})*	*Ka. karua*	0.305(0.002)*
Ku. longirostris	0.421(2x10^{-5})*	*Le. diaphanus*	0.546(4x10^{-8})*	*Ku. latissima*	0.962(5x10^{-22})*
Le. diaphanus	0.497(6x10^{-7})*	*Mo. macrocopa*	0.450(7x10^{-6})*	*Ku. longirostris*	0.610(1x10^{-9})*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Mo. macrocopa	0.407(4x10^{-5})*	*Mi. macleayi*	0.520(2x10^{-7})	*Le. diaphanus*	0.468(3x10^{-6})*
Ni. eximius	0.614(8x10^{-10})*	*Ni. eximius*	0.597(2x10^{-9})*	*Mo. macrocopa*	0.586(4x10^{-9})*
Ox. singalensis	0.280(0.005)*	*Ox. singalensis*	0.285(0.004)*	*Ni. eximius*	0.594(3x10^{-9})*
Pl. denticulatus	0.672(2x10^{-11})*	*Pl. denticulatus*	0.466(3x10^{-6})*	*Ox. singalensis*	0.686(6x10^{-12})*
Pl. laevis	0.634(2x10^{-10})*	*Pl. laevis*	0.619(6x10^{-10})*	*Pl. denticulatus*	0.537(7x10^{-8})*
Alonella excisa		*Bythotrephes longimanus*		*Pl. laevis*	0.698(3x10^{-12})*
Bi. affinis	0.574(9x10^{-9})*	*Al. rustica*	0.292(0.003)*	*Chydorus sphaericus*	
Bi. intermedia	0.472(2x10^{-6})*	*Ao. excisa*	0.420(3x10^{-5})*	*Ac. angustatus*	0.299(0.003)*
Ca. rectirostris	0.360(3x10^{-4})*	*Bi. intermedia*	0.322(0.001)*	*Al. guttata*	0.585(4x10^{-9})*
Ce. megops	0.349(5x10^{-4})*	*Ca. rectirostris*	0.510(3x10^{-7})*	*Al. natalensis*	0.333(0.001)*
Chydorus gibbus	0.331(0.001)*	*Ch. sphaericus*	0.254(0.011)*	*Al. protzi*	0.322(0.001)*
Chydorus piger	0.598(2x10^{-9})*	*Da. curvirostris*	1.000(1x10^{-23})*	*Al. rustica*	0.371(2x10^{-4})*
Da. curvirostris	0.420(3x10^{-5})*	*Da. lumholtzi*	0.534(9x10^{-8})*	*Ao. excisa*	0.771(1x10^{-14})*
Da. lumholtzi	0.444(9x10^{-6})*	*Di. brachyurum*	0.573(9x10^{-9})*	*Bi. affinis*	0.483(1x10^{-6})*
Da. obtusa	0.203(0.041)*	*Di. sarsi*	0.305(0.002)*	*Bi. intermedia*	0.639(1x10^{-10})*
Daphnia sp.	0.232(0.020)*	*Eu. orientalis*	0.512(3x10^{-7})*	*Ca. rectirostris*	0.389(1x10^{-4})*
Di. sarsi	0.585(5x10^{-9})*	*Ka. karua*	0.487(1x10^{-6})*	*Ce. megops*	0.299(0.003)*
Dr. dentata	0.331(0.001)*	*Le. diaphanus*	0.459(4x10^{-6})*	*Ch. gibbus*	0.299(0.003)*
Eu. orientalis	0.577(7x10^{-9})*	*Mo. macrocopa*	0.358(3x10^{-4})*	*Ch. piger*	0.661(4x10^{-11})*
Ka. karua	0.550(4x10^{-8})*	*Mi. macleayi*	0.559(2x10^{-8})*	*Da. curvirostris*	0.254(0.011)*
Ku. latissima	0.590(3x10^{-9})*	*Ni. eximius*	0.337(0.001)*	*Da. lumholtzi*	0.310(0.002)*
Ku. longirostris	0.613(8x10^{-10})*	*Pl. denticulatus*	0.224(0.024)*	*Daphnia* sp.	0.445(8x10^{-6})*
Le. diaphanus	0.686(6x10^{-12})*	*Pl. laevis*	0.333(0.001)*	*Di. brachyurum*	0.276(0.006)*
Pl. denticulatus	0.509(3x10^{-7})*	*Eu. orientalis*	0.467(3x10^{-6})*	*Ku. latissima*	0.661(4x10^{-11})*
Pl. laevis	0.715(7x10^{-13})*	*Ku. longirostris*	0.406(5x10^{-5})*	*Ku. longirostris*	0.817(3x10^{-16})*
Mo. macrocopa	0.583(5x10^{-9})*	*Camptocercus rectirostris*		*Di. sarsi*	0.552(3x10^{-8})*
Mi. macleayi	0.402(6x10^{-5})*	*Da. curvirostris*	0.510(3x10^{-7})*	*Dr. dentata*	0.299(0.003)*
Ni. eximius	0.780(5x10^{-15})*	*Daphnia* sp.	0.402(6x10^{-5})*	*Eu. orientalis*	0.571(1x10^{-8})*
Ox. singalensis	0.650(7x10^{-11})*	Di. sarsi	0.580(6x10^{-9})*	Ka. karua	0.395(7x10^{-5})*

Table 7. *Continued.*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
B. Positive correlations (Continued)					
Allocyclops sp.		*Camptocercus rectirostris* (Continued)		*Chydorus sphaericus* (Continued)	
Cryptocyclops sp.	0.457(5x10^{-6})*	*Le. diaphanus*	0.652(6x10^{-11})*	*Le. diaphanus*	0.670(2x10^{-11})*
Ectocyclops sp.	0.270(0.007)*	*Mi. macleayi*	0.247(0.013)*	*Mo. macrocopa*	0.450(7x10^{-6})*
Mesocyclops sp.	0.260(0.009)*	*Ni. eximius*	0.599(2x10^{-9})*	*Mi. macleayi*	0.271(0.007)*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Paradiaptomus sp.	$0.681(9x10^{-12})$*	*Ox. singalensis*	0.229(0.022)*	*Ni. eximius*	$0.700(2x10^{-12})$*
Biapertura affinis		*Pl. denticulatus*	$0.534(9x10^{-8})$*	*Ox. singalensis*	$0.587(4x10^{-9})$*
Bi. intermedia	0.287(0.004)*	*Pl. laevis*	$0.589(4x10^{-9})$*	*Pl. denticulatus*	$0.584(5x10^{-9})$*
Ce. megops	0.341(0.001)*	*Ceriodaphnia megops*		*Pl. laevis*	$0.751(5x10^{-14})$*
Ch. gibbus	0.341(0.001)*	*Ch. piger*	$0.420(3x10^{-5})$*	*Cryptocyclops* sp.	
Ch. piger	$0.762(2x10^{-14})$*	*Da. obtusa*	$0.681(9x10^{-12})$*	*Diaptomus* sp.	0.232(0.020)*
Da. lumholtzi	$0.461(4x10^{-6})$*	*Daphnia* sp.	0.286(0.004)*	*Ectocyclops* sp.	$0.665(3x10^{-11})$*
Cryptocyclops sp.		*Di. sarsi*	0.246(0.014)*	*Harpacticella* sp.	$0.367(2x10^{-4})$*
Mesocyclops sp.	$0.688(5x10^{-12})$*	*Diaphanosoma sarsi*		*Kurzia longirostris*	
Microcyclops sp.	$0.548(4x10^{-8})$*	*Le. diaphanus*	$0.680(9x10^{-12})$*	*Le. diaphanus*	$0.489(1x10^{-6})$*
Paracyclops sp.	$0.376(2x10^{-4})$*	*Mo. macrocopa*	$0.779(6x10^{-15})$*	*Mo. macrocopa*	0.313(0.002)*
Paradiaptomus sp.	0.342(0.001)*	*Mi. macleayi*	$0.573(9x10^{-9})$*	*Ni. eximius*	$0.694(4x10^{-12})$*
Daphnia curvirostris		*Ni. eximius*	$0.796(2x10^{-15})$*	*Ox. singalensis*	$0.510(3x10^{-7})$*
Da. lumholtzi	$0.534(8x10^{-8})$*	*Ox. singalensis*	$0.528(1x10^{-7})$*	*Pl. denticulatus*	$0.592(3x10^{-9})$*
Di. sarsi	0.305(0.002)*	*Pl. denticulatus*	$0.566(1x10^{-8})$*	*Pl. laevis*	$0.702(2x10^{-12})$*
Eu. orientalis	$0.512(3x10^{-7})$*	*Pl. laevis*	$0.759(3x10^{-14})$*	*Leberis diaphanous*	
Ka. karua	$0.487(1x10^{-6})$*	*Diaptomus* sp.		*Mo. macrocopa*	$0.468(3x10^{-6})$*
Le. diaphanus	$0.459(4x10^{-6})$*	*Ectocyclops* sp.	$0.409(4x10^{-5})$*	*Mi. macleayi*	$0.462(4x10^{-6})$*
Mo. macrocopa	$0.358(3x10^{-4})$*	*Harpacticella* sp.	$0.372(2x10^{-4})$*	*Ni. eximius*	$0.684(7x10^{-12})$*
Mi. macleayi	$0.559(2x10^{-8})$*	*Mesocyclops* sp.	$0.423(2x10^{-5})$*	*Ox. singalensis*	$0.721(5x10^{-13})$*
Ni. eximius	0.337(0.001)*	*Microcyclops* sp.	$0.553(3x10^{-8})$*	*Pl. denticulatus*	$0.459(4x10^{-6})$*
Pl. denticulatus	0.224(0.024)*	*Drepanothrix dentata*		*Pl. laevis*	$0.690(5x10^{-12})$*
Pl. laevis	0.333(0.001)*	*Eu. orientalis*	$0.469(3x10^{-6})$*	*Mesocyclops* sp.	
Daphnia lumholtzi		*Ka. karua*	$0.465(3x10^{-6})$*	*Microcyclops* sp.	$0.660(4x10^{-11})$*
Di. sarsi	$0.565(2x10^{-8})$*	*Ku. latissima*	$0.420(3x10^{-5})$*	*Paracyclops* sp.	0.255(0.011)*
Eu. orientalis	$0.541(6x10^{-8})$*	*Ku. longirostris*	0.246(0.014)*	*Paradiaptomus* sp.	0.209(0.036)*
Ka. karua	$0.833(7x10^{-17})$*	*Le. diaphanus*	$0.391(9x10^{-5})$*	*Paradiaptomus* sp.	0.340(0.001)*
Le. diaphanus	$0.462(4x10^{-6})$*	*Mo. macrocopa*	$0.385(1x10^{-4})$*	*Moina macrocopa*	
Mo. macrocopa	$0.705(2x10^{-12})$*	*Mi. macleayi*	$0.534(9x10^{-8})$*	*Mi. macleayi*	$0.673(2x10^{-11})$*
Mi. macleayi	$0.638(2x10^{-10})$*	*Ni. eximius*	$0.352(4x10^{-4})$*	*Ni. eximius*	$0.598(2x10^{-9})$*
Ni. eximius	0.319(0.001)*	Ox. singalensis	$0.548(4x10^{-8})$*	Ox. singalensis	$0.430(2x10^{-5})$*

Table 7. *Continued.*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
B. Positive correlations (Continued)					
Daphnia lumholtzi (Continued)		*Drepanothrix dentata* (Continued)		*Moina macrocopa* (Continued)	
Ox. singalensis	0.291(0.004)*	*Pl. denticulatus*	0.245(0.014)*	*Pl. denticulatus*	$0.363(3x10^{-4})$*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Pl. laevis	0.319(0.001)*	*Pl. laevis*	0.277(0.006)*	*Pl. laevis*	0.575(8x10^{-9})*
Daphnia obtusa		*Ectocyclops* sp.		*Moinodaphnia macleayi*	
Ku. latissima	0.216(0.030)*	*Harpacticella* sp.	0.478(2x10^{-6})*	*Ni. eximius*	0.349(5x10^{-4})*
Pl. denticulatus	0.343(0.001)*	*Mesocyclops* sp.	0.957(9x10^{-22})*	*Ox. singalensis*	0.262(0.009)*
Daphnia sp.		*Microcyclops* sp.	0.649(8x10^{-11})*	*Pl. denticulatus*	0.218(0.029)*
Di. sarsi	0.357(3x10^{-4})*	*Paracyclops* sp.	0.247(0.013)*	*Pl. laevis*	0.310(0.002)*
Ku. latissima	0.375(2x10^{-4})*	*Paradiaptomus* sp.	0.221(0.026)*	*Nicsmirnovius eximius*	
Ku. longirostris	0.593(3x10^{-9})*	*Euryalona orientalis*		*Ox. singalensis*	0.535(8x10^{-8})*
Ni. eximius	0.479(2x10^{-6})*	*Ka. karua*	0.709(1x10^{-12})*	*Pl. denticulatus*	0.703(2x10^{-12})*
Pl. denticulatus	0.679(1x10^{-11})*	*Ku. latissima*	0.348(5x10^{-4})*	*Pl. laevis*	0.866(4x10^{-18})*
Pl. laevis	0.547(4x10^{-8})*	*Ku. longirostris*	0.408(4x10^{-5})*	*Oxyurella singalensis*	
Diaphanosoma brachyurum		*Le. diaphanus*	0.871(3x10^{-18})*	*Pl. denticulatus*	0.291(0.004)*
Ac. angustatus	0.536(8x10^{-8})*	*Mo. macrocopa*	0.564(2x10^{-8})*	*Pl. laevis*	0.523(2x10^{-7})*
Ao. excisa	0.409(4x10^{-5})*	*Mi. macleayi*	0.541(6x10^{-8})*	*Pleuroxus denticulatus*	
Bi. affinis	0.410(4x10^{-5})*	*Ni. eximius*	0.625(4x10^{-10})*	*Pl. laevis*	0.775(8x10^{-15})*
Bi. intermedia	0.526(1x10^{-7})*	*Ox. singalensis*	0.511(3x10^{-7})*	*Pseudodiaptomus* sp.	
Ca. rectirostris	0.254(0.011)*	*Pl. denticulatus*	0.342(0.001)*	*Afrocyclops* sp.	0.579(7x10^{-9})*
Ch. gibbus	0.536(8x10^{-8})	*Pl. laevis*	0.607(1x10^{-9})*	*Cryptocyclops* sp.	0.377(2x10^{-4})
Da. curvirostris	0.573(9x10^{-9})*	*Harpacticella* sp.		*Diaptomus* sp.	0.372(2x10^{-4})*
Da. lumholtzi	0.633(2x10^{-10})*	*Mesocyclops* sp.	0.487(1x10^{-6})*	*Ectocyclops* sp.	0.470(2x10^{-6})*
Di. sarsi	0.571(1x10^{-8})*	*Microcyclops* sp.	0.451(6x10^{-6})*	*Harpacticella* sp.	0.978(1x10^{-22})*
Dr. dentata	0.536(8x10^{-8})*	*Karualona karua*		*Mesocyclops* sp.	0.479(2x10^{-6})*
Eu. orientalis	0.549(4x10^{-8})*	*Ku. latissima*	0.341(0.001)*	*Microcyclops* sp.	0.461(4x10^{-6})*
Ka. karua	0.868(3x10^{-18})*	*Ku. longirostris*	0.216(0.031)*	Undetermined 3	
Le. diaphanus	0.469(3x10^{-6})*	*Le. diaphanus*	0.601(2x10^{-9})*	*Abdiacyclops* sp.	0.300(0.003)*
Mo. macrocopa	0.671(2x10^{-11})*	*Mo. macrocopa*	0.786(3x10^{-15})*	*Afrocyclops* sp.	0.718(6x10^{-13})*
Mi. macleayi	0.996(2x10^{-23})*	*Mi. macleayi*	0.871(3x10^{-18})*	*Allocyclops* sp.	0.266(0.008)*
Ni. eximius	0.355(4x10^{-4})*	*Ni. eximius*	0.453(6x10^{-6})*	*Cryptocyclops* sp.	0.613(8x10^{-10})*
Ox. singalensis	0.263(0.008)*	*Ox. singalensis*	0.494(7x10^{-7})*	*Diaptomus* sp.	0.396(7x10^{-5})*
Pl. denticulatus	0.223(0.025)*	*Pl. laevis*	0.414(3x10^{-5})*	*Ectocyclops* sp.	0.914(5x10^{-20})*
Pl. laevis	0.316(0.002)*	*Kurzia latissima*		*Harpacticella* sp.	0.441(1x10^{-5})*
Diaphanosoma sarsi		*Ku. longirostris*	0.591(3x10^{-9})*	*Mesocyclops* sp.	0.872(2x10^{-18})*
Dr. dentata	0.350(5x10^{-4})*	Le. diaphanus	0.484(1x10^{-6})*	Microcyclops sp.	0.659(4x10^{-11})*

Table 7. *Continued.*

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
B. Positive correlations (Continued)					

Species 1/species 2	τ (p-value)	Species 1/species 2	τ (p-value)	Species1/species 2	τ (p-value)
Diaphanosoma sarsi (Continued)		*Kurzia latissima* (Continued)		Undetermined 3 (Continued)	
Eu. orientalis	0.645(1x10^{-10})*	*Mo. macrocopa*	0.594(3x10^{-9})*	*Paradiaptomus* sp.	0.251(0.012)*
Ka. karua	0.666(3x10^{-11})*	*Ni. eximius*	0.613(8x10^{-10})*	*Pseudodiaptomus* sp.	0.449(7x10^{-6})*
Ku. latissima	0.591(3x10^{-9})*	*Ox. singalensis*	0.707(1x10^{-12})*		
Ku. longirostris	0.549(4x10^{-8})*	*Pl. denticulatus*	0.532(1x10^{-7})*		
		Pl. laevis	0.704(2x10^{-12})*		

4.2. Species Richness and Diversity

The present study is the first step in an in-depth study of the micro-arthropods assemblage in Memve'ele dam and the tributary river. A total of 5,487 specimens belonged to three classes, eight orders, 20 families, 57 genera and 87 species. Branchiopoda was the most species-rich class (61 species), followed by Copepoda (25 species). Ostracoda was rare and represented by one species. Orders were Anomopoda (38.3%), Calanoida (9.9%), Ctenopoda (6.3%), Cyclopoida (43.9%), Haplopoda (0.3%), Harpacticoida (0.2%), Onychopoda (0.9%), and Podocopida (0.05%). Anomopoda and Cyclopoida were in all sites in both seasons while Harpacticoida was in the rainy season in each site. Branchiopoda and Copepoda combined give 98.9% species and 99.9% of the total collection. Our results are close to the reports in rivers in at the East-Cameroon (61 species of branchiopods listed [34]) where Anomopoda was dominant (92%), followed by Ctenopoda (6.5%) and Cyclestherida (1.5%) [34]. Copepods are often little collected in Lakes. This is the case in lakes Ossa and Mwembe (Dizangue-Cameroon) where only 8 and 11 species respectively of cladocerans were reported [35]. In rivers at the East-Cameroon, The most collected taxa were Chydoridae (67%), Macrothricidae (6.5%) and Daphniidae (5%) [34]. The most collected species were Ectocyclops sp. (10.6%), Cyclops sp. (9.1%), Al. costata (8.9%), Mesocyclops sp. (7.9%), Tropocyclops sp. (7.5%), Se. calanoides (6.8%), Di. sarsi (6.1%), Pl. denticulatus (3.1%), Thermocyclops sp. (2.9%), Da. lumholtzi. Other species were rare. This is contrary to the situation in East-Cameroon where dominants were *Alona* (11%), *Chydorus* (10%) and *Pleuroxus* (8%) [34]. Pattern in our study may depend on the local environmental conditions or the sampling methodology and design. Tolerant species recorded (12 specialists of marine, brackish and freshwater, 20 specialists of brackish and freswater and *Eucyclops* sp. as specialist of marine and brackish water) could adapt and colonize waters if the increasing effects of anthropization and climate change manage to disrupt the balance of environmental conditions, as it is the case in disturbed environments [36]. The species richness was statiscally low in all cases. The species diversity was statiscally high, a highly even assemblage was noted and all assemblages were lowly dominated by a few species. SADs presented a weak concavity appearance, frequently reported in evolved communities [24].

4.3. Community Structure and Functioning

All sites presented a high diversity, a highly even communities and a very low dominance by a few species. A median dissimilarity of assemblages was noted between the dry and the rainy seasons in the dam and Site 4. But it was low in Sites 2 and 3. Between sites, a median dissimilarity existed in the dry season between the dam and Site 4 and other dissimilarities were low. Overall a global positive net association was noted in all sites and the pooled assemblages. Although the adjustment quality of SADs was poor, assemblage in the rainy season in Site 3 fitted BS model (random sharing, without competition), attesting the disturbed state of the assemblage which undergo the process of formation by pioneer species [37]. LL fitted the dry season's assemblage in Site 2 and Site 3, with in each case a low environmental constant. LL model describes communities in which a reduced number of dominants is present (elementary interspecies relations and competition limited to the physical space). Assemblage of the pooled seasons in Site 2 fitted the LN model with a low environmental constant. LL niche partitioning and LN reflect communities with moderately abundant majority of species. Nomocenosis is reported fiting several invertebrate communities including zooplankton in the Arcachon Bay (France) [38]. It characterizes less disturbed environments where strong competitions exist. Given that nomocenosis are associations in which species are influenced by the same factors, they characterize less disturbed environments. ZM fitted SADs in the dam, Site 4, and the pooled sites. In the dam, a high niche diversification and a median fractal dimension were noted in the dry season and the pooled seasons. A low fractal dimension was noted in the rainy season, In Site 2, ZM fitted the assemblage in the rainy season, with a low fractal dimension. Z fitted the pooled seasons' SAD in Site 3 with a very low decay coefficient. In Site 4, a low fractal dimension was noted in the dry season, the rainy season and in the pooled seasons. Z and ZM are reported in evolved communities where a multi-species network structure corresponds to an optimal structure for the circulation of information [39]. Assemblages in each season in the dam, Site 2 in the rainy season, Site 3 in the pooled seasons, Site 4 in each season and in the pooled sites, functioned on the basis of maintaining a complex information network and the sufficient regeneration force.

5. Conclusion

The aim of the study was to establish a baseline of information on the water quality, the biodiversity and the community structure of micro-arthropods in the Memwe'ele dam and the tributary river. Raw water was unfit for direct drinking but presented ideal conditions for fish farming and irrigation for agriculture. A high diversity was noted (three classes, eight orders, 20 families, 57 genera and 87 species) as well as a highly even communities and a very low dominance by a few species. Assemblage functioned in the rainy season in Site 3 as a pioneer community while those in the dry season in Site 2, the pooled seasons in Site 2 and in the dry season in Site 3, operated on the basis of the nomocenosis and therefore were little evolved. Assemblages in the two seasons in the dam and Site 4, in the rainy season in Site 2 and in the pooled seasons in Site 3, were evolved and functioned on the basis of maintaining a complex network of information with a sufficient force of regeneration. The Memve'ele dam, initially built for electricity production, its tributary and the riparian river therefore present a good community of micro-arthropods necessary for the nutrition of aquatic macro-invertebrates and/or macro-vertebrates. In addition to the electricity production, the dam could be exploited for fish production. The detailed study of other groups of zooplankton and even phytoplankton would make it possible to evaluate the overall fishing potential and a fish production perspective. The authorities responsible for surface water management should develop measures to preserve the tributaries of the dam as well as the riparian rivers in order to maintain the natural aquatic microfauna that occur.

Abbreviations

Aa. curvirostris	*Acantholeberis curvirostris* (O. F. Müller, 1776)
Ac. aduncus	*Acroperus aduncus* Sars, 1863
Ac. angustatus	*Acroperus angustatus* G. O. Sars, 1863
Ac. harpae	*Acroperus harpae* (Baird, 1834)
AIC	Akaike Information Criteria
Al. costata	*Alona costata* G. O. Sars, 1862
Ao. excisa	*Alonella excisa* (Fischer, 1854)
Al. guttata	*Alona guttata* G. O. Sars, 1862
Al. natalensis	*Alona natalensis* Sinev, 2008
Al. protzi	*Alona protzi* Hartwig, 1900
Al. quadrangularis	*Alona quadrangularis* (O. F. Müller, 1776)
Al. rectangula	*Alona rectangula* G. O. Sars, 1862
Al. rustica	*Alona rustica* Scott, 1895
ANOVA	Analysis of Variance
Bi. affinis	*Biapertura affinis* (Leydig, 1860)
Bi. intermedia	*Biapertura intermedia* (Sars, 1862)
BIC	Bayesian Information Criteria
BOD_5	Biochemical Oxygen Demand for Five Days
BS	Broken-Stick Model
By. longimanus	*Bythotrephes longimanus* Leydig, 1860
Ca. rectirostris	*Camptocercus rectirostris* Schödler, 1862
Ce. cornuta	*Ceriodaphnia cornuta* G. O. Sars, 1885
Ce. megops	*Ceriodaphnia megops* G. O. Sars, 1862
Ce. quadrangula	*Ceriodaphnia quadrangula* (O. F. Müller, 1785)
Ch. gibbus	*Chydorus gibbus* G. O. Sars, 1890
Ch. ovalis	*Chydorus ovalis* Kurz, 1875
Ch. piger	*Chydorus piger* G. O. Sars, 1862
Ch. sphaericus	*Chydorus sphaericus* (O. F. Müller, 1776)
Chl. a	Chlorophyll a
Cond.	Conductivity
CU	Conventional Unit
Da. curvirostris	*Daphnia curvirostris* O. F. Müller, 1776
Da. lumholtzi	*Daphnia lumholtzi* G. O. Sars, 1885
Da. obtusa	*Daphnia obtusa* Kurz, 1875
df	degree of freedom
Di. brachyurum	*Diaphanosoma brachyurum* (Lievin, 1848)
Di. sarsi	*Diaphanosoma sarsi* Richard, 1894
DO	Dissolved Oxygen
Dr. dentata	*Drepanothrix dentata* (Eurén, 1861)
Eu. orientalis	*Euryalona orientalis* (Daday, 1898)
FTU	Formazine Turbidity Unit
I. acutifrons	*Ilyocryptus acutifrons* G. O. Sars, 1862
I. agilis	*Ilyocryptus agilis* Kurz, 1878
I. sordidus	*Ilyocryptus sordidus* (Liévin, 1848)
Ka. karua	*Karualona karua* (King, 1853)
Ku. latissima	*Kurzia latissima* (Kurz, 1875)
Ku. longirostris	*Kurzia longirostris* (Daday, 1898)
Le. diaphanus	*Leberis diaphanus* (King, 1853)
Li. sinensis	*Limnoithona sinensis* (Burckhardt, 1913)
LL	LogLinear Model
LN	LogNormal Model
Lp. kindtii	*Leptodora kindtii* (Focke, 1844)
Ly. acanthocercoides	*Leydigia acanthocercoides* (Fischer, 1854)
Ly. leydigi	*Leydigia leydigi* (Schödler, 1863)
Ly. quadrangularis	*Leydigia quadrangularis* (Leydig, 1860)
Mi. macleayi	*Moinodaphnia macleayi* (King, 1853)
Mo. brachiata	*Moina brachiata* (Jurine, 1820)
Mo. macrocopa	*Moina macrocopa* (Straus 1820)

Mo. micrura	*Moina micrura* Kurz, 1875
NH_4^+	Ammoniacal Nitrogen
Ni. eximius	*Nicsmirnovius eximius* (Kiser, 1948)
NO_2^-	Nitrites
NO_3^-	Nitrates
NS	Not Significant
OD	Optical Densities
O. singalensis	*Oxyurella singalensis* (Daday, 1898)
Pa. pigra	*Paralona pigra* G. O. Sars, 1862
pH	potential of Hydrogen
Pi. denticulatus	*Picripleuroxus denticulatus* (Birge, 1879)
Pi. laevis	*Picripleuroxus laevis* (G. O. Sars, 1862)
Pi. striatus	*Picripleuroxus striatus* (Schödler, 1862)
Pl. aduncus	*Pleuroxus aduncus* (Jurine, 1820)
Pl. denticulatus	*Pleuroxus denticulatus* Birge, 1879
Pl. laevis	*Pleuroxus laevis* G. O. Sars, 1862
Pl. striatus	*Pleuroxus striatus* Schödler, 1862
Pl. trigonellus	*Pleuroxus trigonellus* (O. F. Müller, 1776)
Pl. uncinatus	*Pleuroxus uncinatus* (Baird, 1850)
Po. pediculus	*Polyphemus pediculus* (Linnaeus, 1761)
PO_4^{3-}	Orthophosphate
Pt-Co	Platinium-Cobalt
R. falcata	*Rhynchotalona falcata* (G. O. Sars, 1862)
R. kistarae	*Rhynchotalona kistarae* Røen, 1973
SADs	Species Abundance Distributions
Sc. kingi	*Scapholeberis kingi* G. O. Sars, 1888
Se. calanoides	*Senecella calanoides* Juday, 1923
se	standard error
Sm. exspinosus	*Simocephalus Exspinosus* (De Geer, 1778)
Sm. vetulus	*Simocephalus vetulus* (O. F. Müller, 1776)
Sr. serricaudatus	*Streblocerus serricaudatus* (Fischer, 1849)
SS	Suspended Solids
St. major	*Stenocypris major* (Baird, 1859)
Temp.	Temperature
Tr. ambigua	*Tretocephala ambigua* (Lilljeborg, 1901)
Turb.	Turbidity
WHO	World Health Organization
WQI	Water Quality Index
Z	Zipf
ZM	Zipf-Mandelbrot

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Data Availability Statement

The data supporting the outcome of this research work is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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