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WATER QUALITY ASSESSMENT USING BENTHIC MACROINVERTEBRATES IN A PERIURBAN STREAM (CAMEROON)

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ABSTRACT

In order to assess the water quality of Nga stream, the right tributary of Mefou, physicochemical variables were coupled to benthic macroinvertebrates communities. Physicochemical results revealed a good health status of the Nga stream, with significant differences of conductivity observed between stations and months ($P < 0.05$). Of the 2553 individuals collected (4 phyla, 7 classes, 15 orders, 74 families and 117 genera), Arthropods (99.25%) was dominated by the class of Hexapods (63.85%), followed by Decapods (35.41%), which were mainly predominated by Atyidae family (34.86%). Ephemeroptera-Plecoptera-Trichoptera (EPT) group (14.69%) constituted 25 families and 42 genera. EPT/Chironomidae density ratio varied significantly between stations and months ($P < 0.05$), while a significant correlation existed between temperature and dissolved oxygen ($P < 0.05$), temperature and pH, ammonia and nitrites ($P < 0.05$), Decapods and dissolved oxygen and Ephemeroptera and low degradable organic matter ($P < 0.05$). The Sorensen's similarity coefficient expressed a close resemblance between stations Nga 1 and 3 (76.09%) and Nga 1 and 4 (77.69%). Shannon and Weaver and Pielou index revealed a diversified and equal distribution of macrozoobenthos downstream. The rank frequency diagram situated station Nga 1 at the growth phase and Nga 2, 3 and 4 at the maturation phase. The Hilsenhoff index (3.30 - 4.96) indicates good to excellent water status. The results of Nga stream could present referential characteristics used to follow up the evolution status of streams in non anthropisized zones of Cameroon.

Keywords: Nga stream, Water quality, Physicochemical variables, Benthic macroinvertebrates, Biocoenotic index, Cameroon.

INTRODUCTION

It is nowadays recognized that aquatic medium constitutes a natural patrimonial component which is indispensable for the well being of the present and future generations, due to multiple anthropic effects that its undergoes with many consequences on water resources and human health (Point, 1999). Therefore, long term management evaluation strategies of hydrosystems have to be permanent, due to the variability of these environment and their communities (Leroy, 2004; Lecerf, 2005). Hence, required tools should be put at the disposal of the institutions in charged of aquatic environments, in order to better understand and manage in a long term these complex and dynamic ecosystems. Physico-chemical or biological variables were used to evaluate the health status of water resources (Meybeck and Helmer, 1992). Although biological analysis were considered more appropriate than the traditional physicho-chemical method in evaluating the level of stress undergone by aquatic ecosystems (Barbour *et al.*, 1999; Macneil *et al.*, 2002), the combination of these two parameters seem to give more complete and satisfactory results (Dias *et al.*, 2008; Foto Menbohan *et al.*, 2011). This reflects the fact that, water quality appears as the principal limiting factor of invertebrates diversity. Amongst the organisms which are currently used in the evaluation of running waters, benthic macroinvertebrates are the preferable biological group due to their high diversity, sedentary character and their variable sensitivity to different environmental stress (pollution or change in the habitat) (Moisan, 2010).

In Cameroon, particularly in Yaounde town, many studies based on the structure of aquatic communities have been conducted in lentic and lotic environments to evaluate their health status, revealing that the Mfoundi river basin is subjected to organic pollution of anthropic origin (Nyamsi, 2004; Zebaze Togouet *et al.*, 2005; Ajeagah *et al.*, 2010; Foto Menbohan *et al.*, 2010; Foto Menbohan *et al.*, 2011). Also, studies conducted by Foto Menbohan *et al.* (2010) on benthic macroinvertebrates community of Nga stream in a peri-urban environment showed that its water is of good health status. However, these studies were limited to biological component, either in urban (Foto Menbohan *et al.*, 2011) or peri-urban environment (Foto Menbohan *et al.*, 2010). In order to complete this lapse and evaluate more profoundly the health status of Nga stream, to confirm previous results, physico-chemical variables coupled to benthic macroinverteberates structure were studied 3 years after. The results obtained from this study would provide viable information which could be used to evaluate the water quality of lotic systems in Cameroon.

MATERIAL AND METHODS

Description of the Sampling Sites

The Centre-South forestry region of Cameroon is located between 3°30' - 3°58' of latitude Nord and between 11°20' - 11°40' of longitude East. The average altitude attends 750 m, the relief is globally accidental, and the zone extends on many high hills of 25 m to 50 m below the plateau (Santoir, 1995).

This region is exposed to an equatorial climate of a specific type, known as "the Yaounde Climate", which is characterised by moderate precipitations (1576 mm/year) and a temperature which varies less with time (Suchel, 1972; Zebazé, 2011), and four unequal seasons which vary from one year to another: a long dry season (Mid November to mid March), a small rainy season

(Mid March to the end of June), a short dry season (July to Mid August) and a long rainy season (Mid August to mid November) were elucidated. The vegetation is of a secondary dense forest type and the river basin is dense with the different streams flowing towards the Nyong and Sanaga rivers. Nga stream, the right tributary of the Mefou, flows towards the peri-urban western part of Yaounde, having a length of about 19,8 km from its source, is situated at 860 m altitude at the foot of Nkoloman and Nkolobot mountains. It flows into a less anthropic river basin, particularly covered by vegetation of a secondary dense forest type, with the presence of herbs and tall trees in some areas while other areas are exploited for agriculture purposes.

Samples were collected twice a month in the morning (8 to 10 a.m.) from January to June 2010, during 12 campaigns. Four sampling stations were selected namely: stations Nga 1 (N 1), Nga 2 (N 2), Nga 3 (N 3) and Nga 4 (N 4) for this hydrobiological and eco-environmental research on the Nga stream.

Nga 1 (3°90 N and 11°36 E) with an altitude of 810 m, is located at about 1,3 Km from the source.
Nga 2 (3°86 N and 11°38 E) with an altitude of 740 m and found in the midstream, is located at about 8.5 Km from the source.
Nga 3 (3°86 N et 11°41 E) with an altitude of 720 m and found at the down stream, is located at about 13 Km from the source.
Nga 4 (3°84 N et 11°45 E) with an altitude of 690 m, is situated at about 500 m upstream of the confluent of Nga with Mefou.

Physico-chemical Parameters

Measuring of physical and chemical parameters of water at the different sampling points was done according to Rodier (1996) and APHA (1998). Temperature (°C), pH, conductivity and percentage of oxygen saturation were measured *in situ*. In the laboratory, phosphates and nitrates values were determined by colorimetry using HACH DR/2800 spectrophotometer while oxydability was measured by complexometry.

Sampling of Benthic Macroinvertebrates

Macroinvertebrates were collected using a 30 x 30 cm kick-net with a 250 µm mesh size. Care was taking to include all possible habitats over representative sections of the stream (10 m samples), similar to the multi-habitat sampling procedure proposed by Barbour *et al.* (1999). In the laboratory, the organisms were washed with water, handpicked from samples and preserved in 70% alcohol for subsequent counting and identification up to the genus level using a stereoscopic microscope Wild M 5. The identification keys of Durand and Levêque (1991), Tachet *et al.* (2006) and (Moisan, 2006; Moisan, 2010) were used.

Statistical Treatment

The parametric and non parametric analysis of variance tests (One way ANOVA and Kruskal-Wallis) were used to compare the spatio-temporal variation of the physical and chemical parameters values, the mean abundance of the different families of macroinvertebrates and the EPT/Chronomidae density ratio,between the different sampling stations and from one month to another. The Spearman correlation coefficient was used to determine the link between physical and physical variables on one hand, and biological variables on the other hand. The SPSS 16.0 logistic was used in all cases. The level of statistical significance was maintained at 95 % ($P < 0.05$). The level of maturation of organisms was appreciated using the rank frequency diagram (Frontier, 1976) and their sensitivity to pollution by Hilsenhoff index, which takes into account the tolerance level attributed to each organism or the group of organisms that constitute the community (Hilsenhoff, 1988).

PHYSICO-CHEMICAL RESULTS

Temperature varied between 20.75 °C (in May at station Nga 1) and 24.9 °C (in January at station Nga 2) with a thermal amplitude of 4.15 °C (Figure 1 a). Dissolved oxygen was globally high all along the stream, with values situated between 64.31 % and 92.65 % (Figure 1 b). The pH values varied between 6.29 and 7.07 (Figure 1 c), while oxydability values were situated between 0.59 mg/L and 18.36 mg/L (Figure 1 e). No significant differences ($P > 0.05$), were observed for these four variables between the different station and from one month to another. High values (96.2 µS/cm) and low values (12,9 µS/cm) of conductivity were recorded at the stations Nga 1 during the months of April and January respectively (Figure 1 d). These variations showed a significant difference between the different stations, same as from one month to another ($P < 0.05$). The same variation trend was observed for ammonia, Nitrates and phosphates, though with relatively low values of 0.59 mg/L, 0.017 mg/L and 0.98 mg/L respectively (Figure 1 f, g and h).

BIOLOGICAL RESULTS

Relative Abundance of Benthic Macroinvertebrates

A total of 48 campaigns were realised for 2553 organisms collected. Most of these organisms belong to the phyla of Arthropoda (99.25 %), Mollusca (0.39 %), Annelida (0.20 %) and Nemathelmintha (0.16 %). All these organisms are distributed under 7 classes, 15 orders, 74 families and 117 genus. The class of Hexapoda dominated (63.85 %) with 8 orders, 66 families and 111 genus, followed by the class of Crustaceans (35.41 %) which counts 1 order, 2 families and 2 genus. The classes of Oligochaeta, Acheta, Gastropoda, Bivalva and Gordiaca represented 0.74 % of the total relative abundance. Of the 15 orders identified, 9 (Decapoda: 35.41 %; Coleoptera: 21.19 %; Odonata: 14.02 % ; Hemiptera: 10.46 %; Ephemeroptera: 9.09 %; Plecoptera: 3.76 %; Diptera: 2.27 %; Trichoptera: 1.87 % and Dictyoptera: 1.21 %) were present in all stations through out the study period. The remaining orders (Lumbriculida, Haplotaxida, Rhynchobdellida, Basomatophora, Eulamellibrancha and Gordioida) appeared irregularly, representing 0.75% of the total abundance (Figure 2).

Variation of Taxonomic Richness, EPT Index and EPT/Chironomidae Density Ratio

The taxonomic richness increases slightly from upstream to downstream with a general mean value of 68 ± 5.66 genus and 48 ± 5. 48 families for a monthly mean value of 56 ± 6, 29 genus and 42,17 ± 4,02 families. The variations observed did not show any significant difference between the different stations of the stream and from one month to another ($P > 0.05$). The mean values of EPT index (Ephemeroptera, Plecoptera and Trichoptera) was 15.5 ± 2.52, while that of EPT/Chronomidae density ratio was 19.42 ± 7.42 (Table 1) with a monthly mean value of 13.82 ± 9.06 (Table 2). This ratio varied significantly between the different stations of the stream and from one month to another ($P < 0.05$).

Correlation Analysis between Variables

A positive and significant correlation was observed between temperature and dissolved oxygen content ($r = 0.43$; $P < 0.05$), temperature and pH ($r= 0.6$; $P < 0.05$) and between ammonia and nitrites ($r =0.61$; $P < 0.05$). Also, a positive correlation was noted between Decapods and high dissolved oxygen content ($r = 0.44$; $P < 0.05$) and between Ephemeroptera and low degradable organic matter in water (r = 0.41; P 0 <.0.05).

Variation of Sorensen's Similarity and Diversity Index

The degree of similarity among benthic macroinvertebrates fauna at the four sampling stations calculated from the relative abundance of the different families showed a high close similarity between the stations Nga 1 and 3 (76.09 %) and Nga 1 and 4 (77.67 %) compared to the other stations (Table 3). Also, no significant difference was observed between the different stations of the stream and from one month to another ($P > 0.05$).

Shannon and Weaver index (H') varied between 3.47 bits/ind (Nga 1) and 3.98 bits/ind. (Nga 4). The Pielou index of equitability (J) followed the same variation trend (Figure 3), indicating a more diversified and equal distribution of macrozoobenthos in the downstream of the Nga stream.

Variation of the Rank Frequency Diagram (RFD)

The variation profile of the rank frequency diagram realised from the abundance of the different families showed that: station Nga 1 is at the growth phase (phase I), which is characterised by a start of ecological succession (Figure 4 a); stations Nga 2, 3 and 4 are at the maturation phase (phase II), which is materialised by the presence of many families with high frequencies. No significant difference ($P > 0,05$) was observed between the different stations of the stream, nor between the different months (Figure 5b).

Spatial Variation of Hilsenhoff Index (FBI)

The Hilsenhoff index values varied from one station to another with minimal value (3.30) obtained at the station Nga 3 and maximal value (4,96) at the station Nga 2 (Figure 5). A significant difference was observed between the different stations of the stream ($P < 0.05$).

DISCUSSION

Temperature variation of the Nga stream is close to that of environmental temperature with slight increase from upstream to downstream. These variations could reflect the oligotrophic character of streams in mountainous areas which are subjected to less anthropic action (Vannote *et al*., 1980; Lecerf, 2005). The water pH limit (6.29 – 7.07 UC) is situated at an interval which favours the development of most organism groups (AE, 1999).

The positive correlation observed between temperature and dissolved oxygen content on one hand, and between temperature and pH on the other hand, is in accordance with the observations of Devidal *et al.* (2007). These authors revealed that in forest zone, heating of water by solar rays coupled to high photosynthetic activities of river basin, natural ventilation and the presence of rapid flow rate and curved flow of water which lead to disturbance and recirculation of water, favour reoxygenation of water at the water/air interface. This phenomenon may accelerate metabolic activities leading to an increase of water pH.

In line with AE (1999), the percentage of oxygen saturation (≥ 70 %) could indicate that the Nga stream is appropriate for the production of potable water, if the flow rate is favourable. Low values of oxydability, diverse ions (NO_2^-, PO_4^{3-}, NH_4^+) and conductivity recorded throughout the study period could indicate on one hand, low mineralization of water, and on the other hand, a reduction in organic matter loads, thus indicating good water quality. However, our results are different from those observed in urban streams of the Mfoundi river basin (Foto, 1989; Nyamsi, 2004; Foto *et al*., 2006), where average oxygen content values of 25 %, high values of conductivity (≥ 3500 µS/cm), very high values of NH_4^+ (3,2 – 27,2 mg/L) and PO_4^{3-} (1,83 - 12,7 mg/L) ions were obtained. According to Charvet. (1995), Tachet *et al.* (2006), (Moisan and Pelletier, 2008), a majority of aquatic insects are very sensitive to pollution and any perturbation of their environment following a modification of habitat will lead to their disappearance. The predominance and great diversity of insects, high percentage of EPT coupled to low density of Chironomidae may reflect a good health status of the Nga stream and its relatively less anthropisized state. However, a decrease in taxonomic richness was observed during this study (monthly mean value of 31.6 families) compared to 42.17 families recorded by Foto Menbohan *et* *al.* (2010). Also, the predominance of Atyidae Decapoda (34.86 %) with a positive correlation with high dissolved oxygen content could be attributed to good oxygenation of the Nga stream. Thus, Tachet *et al.* (2006), revealed that freshwater Decapoda crustaceans multiply in well oxygenated environments and are very sensitive to a reduction of dissolved oxygen content in water, what generally provoke their disappearance.

The benthic macroinvertebrates communities of the Nga stream are essentially represented by Arthropods (99.5%) with a predominance of the family Atyidae (35.41 %), despite the slight decrease of Atyidae observed compared to that recorded (49.9 %) by Foto Menbohan *et al.* (2010). This temporal progressive reduction of Atyidae family coupled to a decrease of taxonomic richness could be a sign of a start of anthropisation in the Nga stream. On the other hand, the family of Atyidae has been totally absent in urban streams of the Mfoundi river basin belonging to the same ecological region, where a remarkable emergence and proliferation of Molluscs (61.8 % and 55.0 %) and Annelids (9.7 % and 16.7 %) were recorded respectively by Kiampi (2004) and Nangmo (2004). This fauna discrepancy could reflect the relatively non polluted status of the Nga stream that flows in a river basin which is less subjected to anthropic action.

With the exception of the station Nga 2, which is subjected to the negative impacts of the Chad-Cameroon pipeline, high mean values of diversity, Shannnon and Weaver and Pielou index recorded could reflect a good integrity of the hydrosytem (Fisher *et al.*, 1982), favouring the development of a large number of species (Foto Menbohan *et al.*, 2010). This results bind with the values of Sörensen's similarity index which show a great fauna affinity between the stations Nga 1 and 3 (76.09 %) and Nga 1 and 4 (77.67 %).

The RFD profile, which indicates that benthic macroinvertebrates reach their maturation phase and high diversity in the downstream, are in conformity with the Continuum Fluvial Concept of Vannote *et al.* (1980). These results are in line with the evolution of the diversity index which shows an increase of diversity from upstream to downstream. Low values of FBI index could also explain the high abundance of less sensitive benthic macroinvertebrates taxa to pollution, as it has been shown that low values of this index indicate a decrease of polluo-tolerant taxa (Hilsenhoff, 1988; Bode *et al.*, 2002). This index also indicates that the water quality of Nga stream varies between good and excellent as previously observed by Foto Menbohan *et al.* (2010).

The good status of Nga stream and its great taxonomic richness could be link to the relatively non pertubated state of its river basin and to the characteristics of streams found at the source of river basin in non anthropisized mountainous forest zone, where vegetation is known to be very dense. Thus, Lecerf (2005) mentioned that death leafs debris contribute about 95 % of carbon flux in streams found at the source of a river basin.

CONCLUSION

It can be concluded from this study that, high dissolved oxygen content, low water acidity, low values of diverse ions and their low spatial-temporal variation show that the water of Nga stream are of good quality and is not presently subjected to a perceptible anthropic action. Benthic macroinvertebrates community is rich and diversified. The great diversity obtained compared to previous results coupled to the diversity index of Shannon and Weaver, equitability index of Piélou, FBI and EPT index, EPT/Chironomidae density ratio and the rank frequency diagrams show that, the integrity of this stream could present referential characteristics being used to follow up the evolution status of streams of the ecological regions in the Centre-south forest zone of Cameroon. Also, future investigations of streams in non anthropic zones are still vital to follow up the evolution of Atiydae family which could serve as indicators of stream not subjected to anthropisation.

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Table-1. Variation of taxonomic richness, EPT index and EPT/Chronomidae density ratio at the four sampled stations

Indicators	Stations				Mean and standard deviation
	N_1	N_2	N_3	N_4	
Number of genera	63	70	70	71	68 ± 5,66
Nomber of families	47	45	44	56	48 ± 5,48
EPT index	13	15	15	19	15,5 ± 2,52
EPT/Chironomidae density ratio	23,73	21,24	24,24	8,47	19,42 ± 7,42

Table-2. Monthly variation of taxonomic richness, EPT index and EPT/Chronomidae density ratio

Indicators	Months						Mean and standard deviation
	January	Febraury	March	April	May	June	
Nomber of genera	46	64	54	61	57	54	56 ± 6,29
Nomber of families	41	45	43	48	37	39	42,17 ± 4,02
EPT index	13	15	13	15	12	12	13,33 ±1,37
EPT/Chironomidae density ratio	26,47	11,16	12,64			5,00	13,82 ± 9,06

Table-3. Sörensen's similarity index (%) among stations applied to benthic Macroinvertebrates communities.

Stations	N1	N2	N3	N4
N1	-	72.53	76.09	77.67
N2		-	74.16	75.25
N3			-	74.00
N4				-

Figure-1. Spatiotemporal variation of physicochemical parameters measured during the study period

(a: Temperature; b: Dissolved oxygen; c: pH; d: Conductivity; e: Oxydability; f: ammonia; g: Nitrites; h: Phosphates).

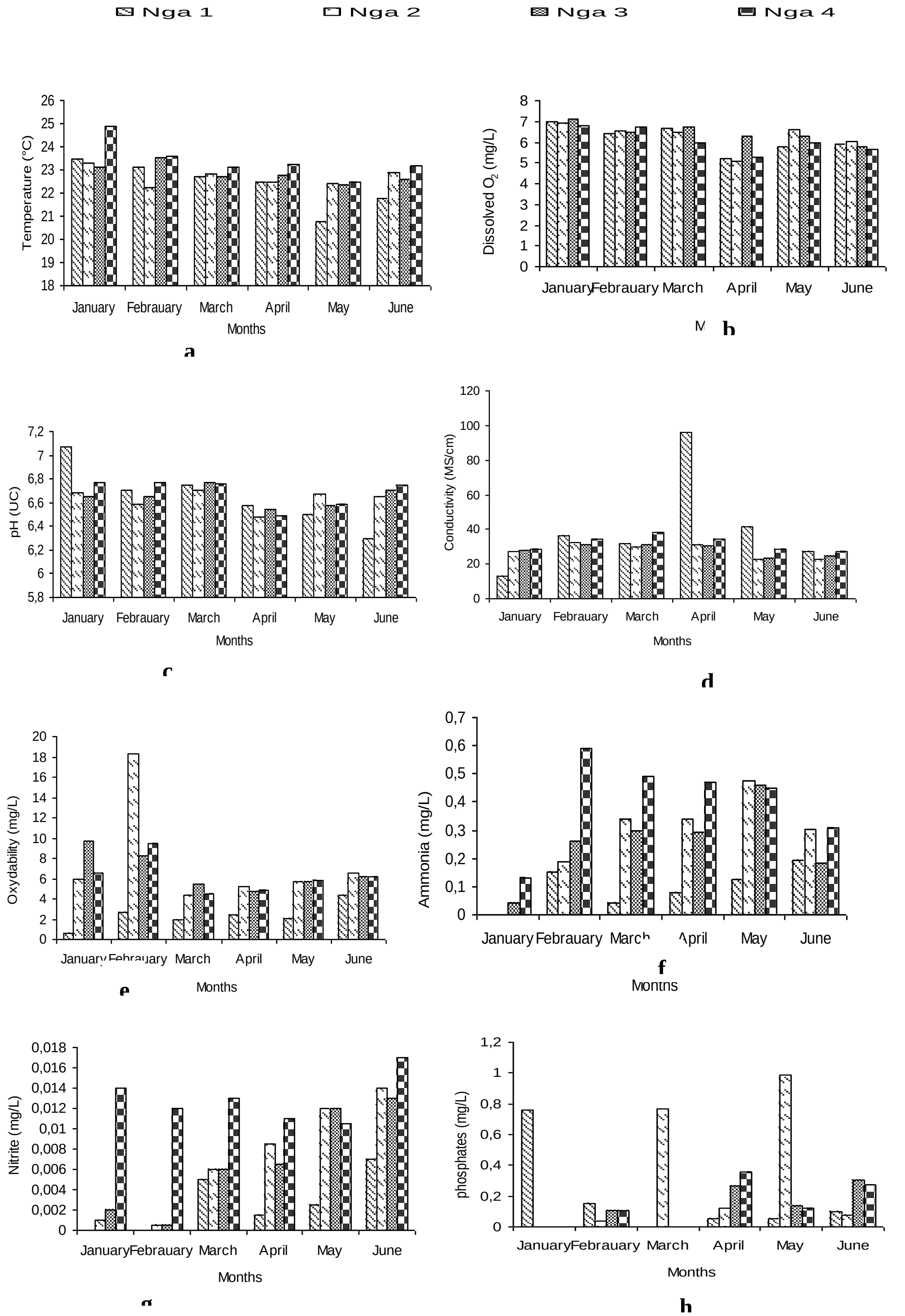

Figure-2. Relative abundance of the different orders of benthic macroinvertebrates recorded during the study period

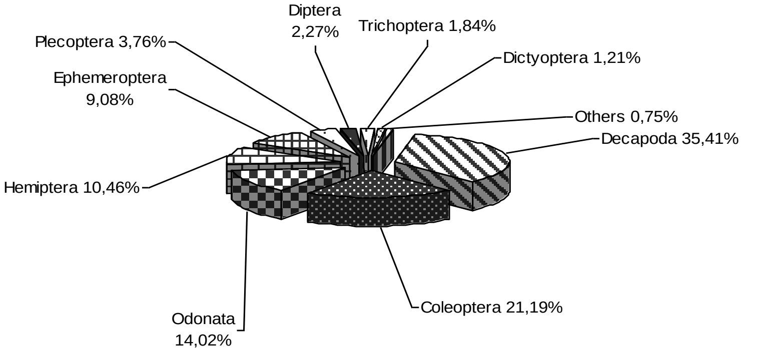

Figure-3. Spatial variation of Shannon and Weaver, and Pielou index at the four sampled stations.

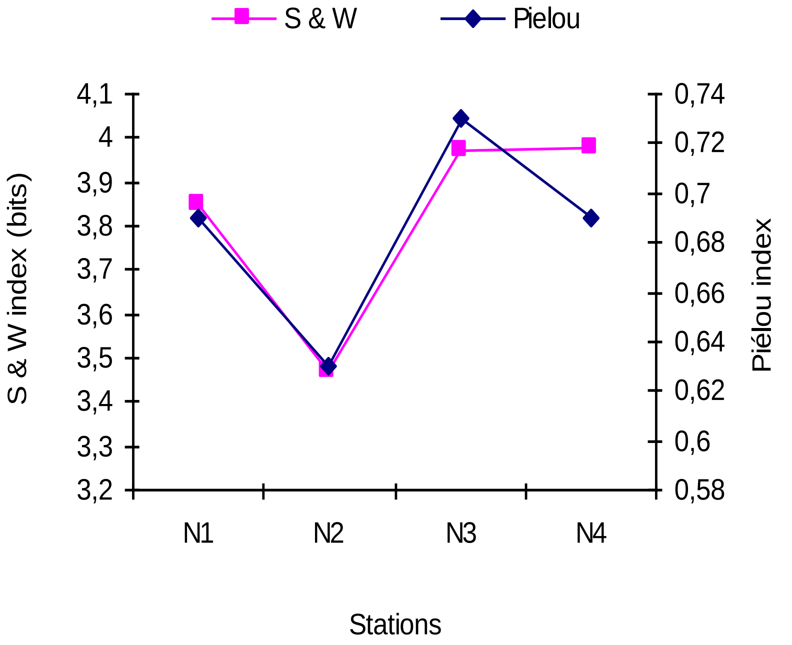

Figure-4. Spatial (a) and temporal (b) variation of rank frequency diagram during the study period.

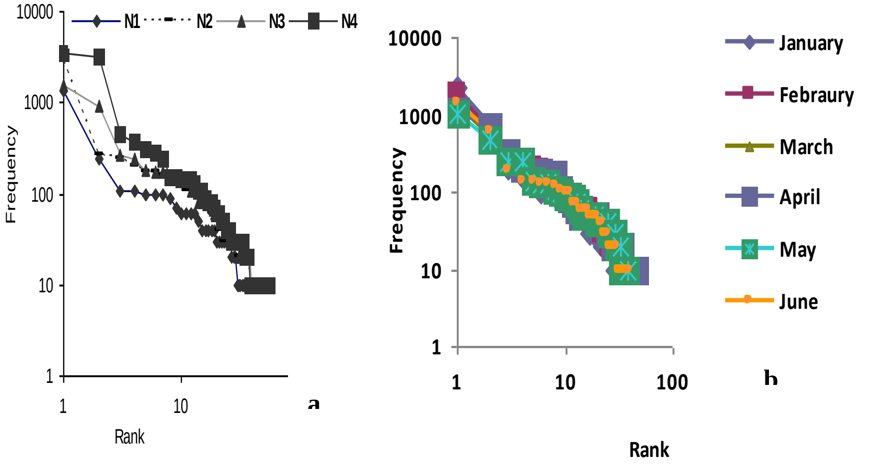

Figure-5. Variation of Hilsenhoff index during the study period