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Effects of macrophytes on aquatic macro-invertebrates in urban polluted lentic ecosystem: case of the man-made lakes of Yamoussoukro (Ivory Coast)

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Abstract

Macrophtytes affect water resource utilisation, but little is known about its impacts on biodiversity in aquatic ecosystems particularly in Ivory Coast. This study allowed assessing the effects of macrophytes on aquatic macro-invertebrates in the urban lakes of Yamoussoukro. Macro-invertebrates were collected on twelve occasions at fourteen sites with macrophyte mats (Group 1) and at fourteen sites without macrophyte (Group 2) using a hand-net and a Van Veen grab. The diversity of the community was assessed in each group of sites. A total of 108 taxa distributed among five classes, twelve orders, 53 families and comprising 22074 individuals were recorded. The group 1 registered 84 taxa belonging to four classes, eleven orders and 46 families (50.50% of total abundance). The group 2 recorded 76 taxa comprising four classes, eleven orders and 27 families (49.50% of total abundance). Insecta were most diversified both in group 1 (84.2%) and group 2 (76.9%). Gasteropoda, especially *Melanoides tuberculata* and *Physa marmorata* were most abundant in each group (respectively 91% and 68.5%). Variations in Rarefied richness, abundance, Shannon-Weiner Diversity and Pielou's Evenness Indexes between the two groups were not statistically significant (Mann-Withney test, $p > 0.05$). Scrapers were quantitatively (Group 1= 79%; Group 2= 61%) dominant in the two groups. Each group was mainly characterized by one family of Diptera (Tabanidae for group 1 and Culicidae for group 2) which are frequently vectors of various disease agents. Influence of macrophytes on macro-invertebrates in Yamoussoukro lakes was not perceptible because of their high level of pollution.

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Introduction

Natural resources are, these days, confronted to a continuous deterioration due to the anthropogenic pressure, the climatic risks and the action of the intrusive species (Amani and Barmo, 2010). The proliferation of invasive plants happened generally in disturbed environments and is intensively modified by human activities (Vander Zanden *et al.*, 2004). These intrusive plants, by their presence and their contributions in coarse remains, appear to be a fundamental element of the control of the structuration of aquatic populations (Peterson *et al.*, 1992; Luken and Thieret, 1997).

They have the capacity to influence the surrounding community by the change or the modification of their original habitat. Furthermore, the aquatic vegetables govern the equilibrium between the entries of external organic matters and the native primary production (Conners and Naiman, 1984; Cummins, 1984 and 1989). Indeed, preventing the penetration of the solar radiation, the free-floating aquatic plant decrease the photosynthesis of the primary producers, the lower part of food webs in freshwater. Moreover, their rapid growth results in the appearance of dense mat on water surface which can bother the multiple utilizations of the resource (Center *et al.,* 2002).

Urban aquatic systems, specifically lentic systems, are more exposed to eutrophication phenomenon. Speeded eutrophication in urban lakes is mainly due to the effluents released without adequate treatment into these waters (Aw, 2009).

This situation in urban ecosystems can make them reservoirs of micro-organisms and caused biodiversity loss (Kouamé *et al.*, 2011).

The socio-economic impacts of the free-floating aquatic plants on aquatic systems are well documented, yet the impacts on aquatic biodiversity, particularly invertebrate biodiversity, are less well understood (Villamagna and Murphy, 2010). The aquatic macroinvertebrates presenting variable sensitivity to the environmental conditions constitute the ideal bioindicators to assess the effects of aquatic weeds on the biodiversity (Thirion, 2000).

These organisms have been used like ecological indicators in several works (Lyons and Kelly-Quinn, 2003; Varga, 2003; Moretti and Callisto, 2005). The use of aquatic macro-invertebrates like biological indicators is explained by their presence on the whole of the aquatic ecosystems with a very high taxonomic diversity. They present a relative stability in the time with populations sufficiently sedentary to establish a good correspondence with the conditions of the environment.

Several studies carried on the influence of the intrusive plants on macro-invertebrates communities. The majority of these works found reduced diversity and a deterioration of macro-invertebrate habitat (Thomaz *et al.*, 2008; Kovalenko *et al.*, 2010; Coetzee *et al.*, 2014) under macrophyte mats. However, Masifwa *et al.* (2001) observed an increase in invertebrate abundance at the edge of water hyacinth mats on Lake Victoria in Uganda.

In Ivory Coast, except some works having treated of macro-invertebrates pledged to aquatic floating plants (Sankaré, 1991; Kouamé *et al.*, 2010), there is little information relative to the impact of the vegetable cover on these organisms.

This study aimed to: (1) inventory the macro-invertebrate community and their trophic structure in Yamoussoukro man-made lakes and (2) assess the effects of floating macrophytes on aquatic macro-invertebrates populations in these lakes.

Material and methods

Study area and sampling sites

The study was conducted in Yamoussoukro (the political capital of Ivory Coast) located in the center of the country between 6°40' and 7°00'N, and 5°10' and 5°20'W (Fig. 1).

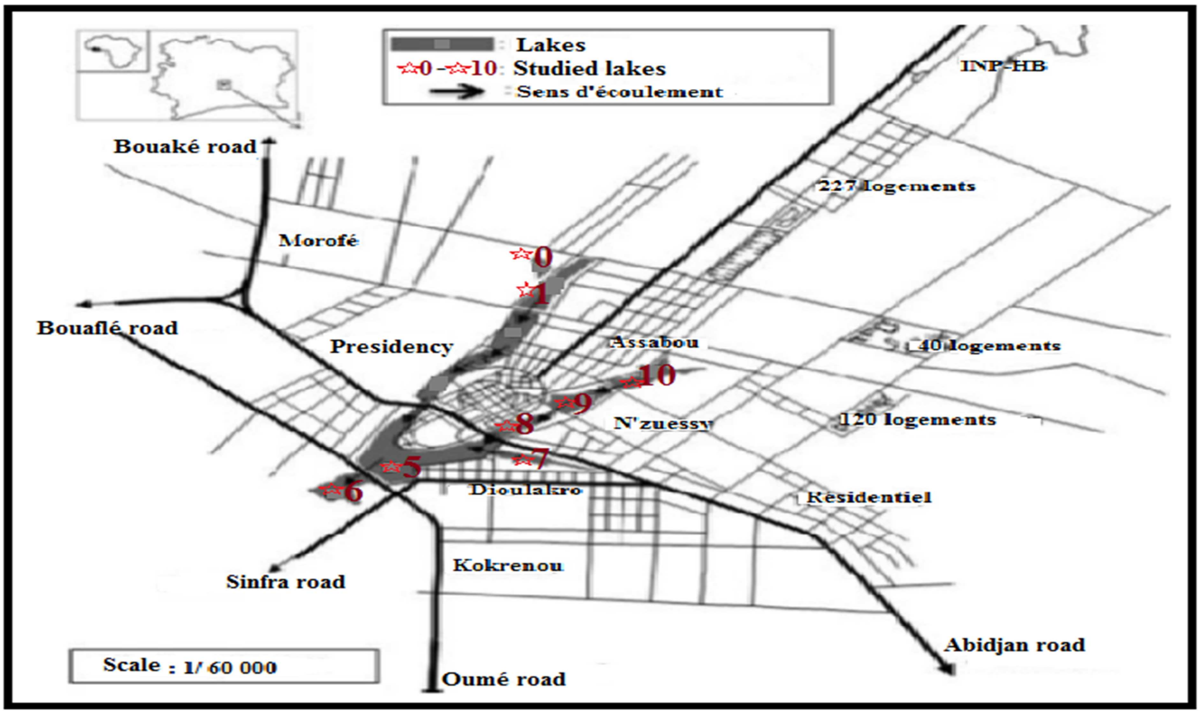

Fig. 1. Location of the study area showing the eight studied lakes of Yamoussoukro (Yvory Coast).

There are in this town, 31 lakes of which ten man-made lakes which communicate with each other by gravity and form a complex system covering approximately 140 ha with a catchment area close to 28.5 Km^2.

This study carried on seven (7) man-made lakes (lake1, lake 5, lake 6, lake 7, lake 8, lake 9 and lake 10) and one natural lake (lake 0). On these lakes, 28 sampling sites have been chosen approximately 3 m from the water's edge. The number of sites per lakes depends of the surface of each lake. So, seven sampling sites were defined on the lake 5, four on lakes 0 and 1, three on lakes 6, 8 and 9, two on lakes 7 and 10. With the exception of lakes 7 and 9, sites with macrophytes and sites without macrophytes have been defined on each lake. According to the presence or absence of macrophyte at each site, they were clustered into two groups. Fourteen sites (group1) had permanent mats of and the other 14 sites (group 2) had no macrophytes cover. The characteristics of each site were shown in Table 1. These urban man-made lakes receive wastewater and solid waste from various human activities (domestic wastewater and solid waste, urban agriculture, schools, hospitals, hotels, restaurants, military camps, car washing services, car garages, gas stations, pasture of the cattle, washing on the banks of lakes) which make them very eutrophicated. Originally designed to embellish the city, 70% of the man-made lakes of Yamoussoukro are currently covered by macrophytes.

Macro-invertebrates sampling and identification

Samples were collected each two months during 12 campaigns (between December 2015 and December 2017) at each sampling site. Macroinvertebrates were sampled using a hand net (250 µm mesh, 50 cm length) and a Van Veen grab of 0.05 m^2 internal area.

Two replicate samples were collected at each site and at each date. The samples were sieved in the field through a 1mm mesh, and the material retained on the mesh was immediately fixed in 70% alcohol. In the laboratory, the samples were washed using 1 mm sieves, sorted and identified using stereomicroscope (Olympus SZ 40). Macroinvertebrates were counted and identified to the lowest taxonomic level by means of the keys in Dejoux *et al.* (1981), Day *et al.* (2001a and 2001b), De Moor *et al.* (2003 and 2003b), Stals and De Moor (2007) for Insecta, Tachet *et al.* (2010) for other Insecta, Acheata and Oligocheata , Brown

(1994) and Bony *et al.* (2008) for Gasteropoda. After identification, each taxon was allocated to a functional feeding group according to their trophic category as assigned by Tachet *et al.* (2010).

Data analysis

Macroinvertebrates structure was described through taxonomic composition, abundance of individuals, Shannon-Weiner index, Pielou's Evenness index, frequency of occurrence, rarefied richness and feeding groups. Taxa richness was rarefied to eliminate any bias related to differences in abundances between samples (Heck *et al.*, 1975; Edia *et al.*, 2016). Calculations were performed using the lowest abundance (4 individuals for this study) found in all sites as the target number of individuals (Oksanen *et al.*, 2013). Frequency of occurrence (FO) is the percentage of samples in which each taxon occurred. It was calculated according to Dajoz (2000) to gives some information on the number of taxa frequently met in each site without any indication on their quantitative importance (Lauzanne, 1976; Hyslop, 1980).

Before performed calculation, sampling sites were divided into two groups: sites with macrophyte mats (Group 1) and sites without macrophytes (Group 2).Variations in diversity measurements between group 1 and group 2were determined using Mann-Withney test in order to assess the variability of these metrics. Before performing the comparison test, the normality of data was checked by Shapiro test ($P > 0.05$ at each group). The analyses were performed using packages for the R 3.0.2 freeware (R Core Team, 2013).

Relative specific richness and abundance of macroinvertebrates feeding groups were determined according to Tachet *et al.* (2010) for each group, to assess the trophic structuration. Then the similarity index of Sorensen (Cs) was used to assess the similarity in taxonomic composition between group 1 and group 2. This index combines three variables: *a*, the number of taxa common to both group 1 and group 2; *b*, the number of taxa presents only in group 1 ; and *c*, the number of taxa presents only in group 2. Calculations were performed according to (Sorensen, 1948).

Indicator values (IndVal) were calculated according to Dufrene and Legendre (1997) to identify the most characteristic taxa for group 1 and group 2. The statistical significance of the indicator values was evaluated using a randomization procedure with 999 permutations (Dufrene and Legendre, 1997). The analyses were performed using packages for the R 3.0.2 freeware (R Core Team, 2013).

Results

Taxonomic composition

The composition of the macro invertebrate assemblages is shown in Table 2. A total of 108 different taxa belonging to six Classes (Insecta, Gastropoda, Acheata, Oligochaeta, Gordiacea and Tubellaria), twelve orders and53 families comprising 22072 individuals were collected. Of the taxa collected, nine were identified to family level, 85 to genus and 13 to species level. Taxonomic richness was dominated by insects (83.3%): Coleoptera (26.4%), Diptera (23%), Hemiptera (20.9%) and Odonata (17.6%).Gasteropoda were numerically most important with 72% of number of individuals collected. Group 1 recorded 14 161 individuals (84 taxa), distributed among four classes, 12 orders and 46 families while group 2 counted 10 928 individuals (76 taxa) belonging to four classes, 11 orders and 45 families. Rarefied richness oscillated between 8.9 and 30.8 in group 1 whereas in group 2 it varied between 13.5 and 25. Samples were dominated by Insect both in group 1(84.2% of taxonomic richness) and group 2 (76.9% of taxonomic richness).

In this class, Coleoptera (21 taxa) and Hemiptera (18 taxa) were most important in group 1while in group 2, Diptera (19 taxa) recorded the highest number of taxa. *Physa marmorata* and *Melanoides tuberculata* (Gasteropoda) were most abundant both in group 1 (91%) and in group 2 (68.5%). More Trichoptera were found under macrophyte mats (Group 1). Out of Achaeta and Oligochaeta, macroinvertebrates collected in group 1 were relatively most abundant and diversify. Yet, difference in rarefied richness (Fig. 2A) and individual's abundance (Fig 2B) calculated for each group of sites was not significant (Mann-Withney test, p>0.05).

Table 1. Geoagraphical coordinates and percentage of vegetable cover vegetable cover of sampling sites and surface of studied lakes of Yamoussoukro.

		Cordinates			
Lakes	Stations	S	E	Cover (%)	Surface of lakes(Km²)
Lake 0	S1	248913	756343	100	0.13
Lake 0	S4	248931	756480	100	
Lake 0	S2	248919	756355	0	
Lake 0	S3	248925	756391	0	
Lake 1	S6	249180	756852	100	0.15
Lake 1	S7	249331	756828	100	
Lake 1	S8	249029	756232	100	
Lake 1	S5	248949	756541	0	
Lake 5	S9	248825	755431	100	0.45
Lake 5	S15	247660	754411	100	
Lake 5	S10	248915	754213	0	
Lake 5	S11	247924	756734	0	
Lake 5	S12	247923	753669	0	
Lake 5	S13	247591	753379	0	
Lake 5	S14	247291	753704	0	
Lake 6	S16	247271	753522	100	0.10
Lake 6	S18	246881	753251	100	
Lake 6	S17	247041	753064	0	
Lake 7	S20	248715	753743	100	0.08
Lake 7	S19	248577	753815	100	
Lake 8	S22	248572	750246	100	0.10
Lake 8	S21	248674	754129	0	
Lake 8	S23	249055	754407	0	
Lake 9	S24	249221	754500	0	0.10
Lake 9	S25	249211	754808	0	
Lake 9	S26	249496	754751	0	
Lake 10	S27	249736	754899	100	0.11
Lake 10	S28	249622	754963	100	

Frequency of occurrence (FO)

Very frequent taxa (FO ≥ 50%) represented 24.1% and 24.68% of taxonomic richness respectively in group 1 and in group 2 (Table 3). these taxa were composed of seven Gasteropoda and 13 Insecta (five Coleoptera, three Diptera, three Hemiptera, one Odonata and one Ephemeroptera) in group 1.

The group 2 recorded one Acheata, five Gasteropoda and ten Insecta (three coleoptera, three Diptera, two Ephemeroptera and two Hemiptera). Rare taxa (FO <25%) were most represented in the two groups of sites (62.65% in group 1 and 59.74% in group 2). Two Gasteropoda (*Physa marmorata* and *Melanoides tuberculata*) were found at each site and each sampling occasion (FO =100%) both in group 1 and group 2. Trichoptera observed in each group of sites were found with rare occurrence.

Shannon-Weiner Diversity Index and Evenness Index

The Shannon-Weiner Diversity (H') Index (Fig. 2C) and Pielou's Evenness Index (J) (Fig. 2D) were calculated for each sample to determine macroinvertebrate structure in the two groups of sites. The high value of Shannon index (3.19) was observed in group 1 whereas the low one (0.8) was registered in group 2. Evenness index varied from

0.25 to 0.60 in group 1 while this index oscillated between 0.21 and 0.59 in group 2.Variations in these metrics between group 1 and group 2 were not significant (Mann-Withney test, $p > 0.05$).

Functional feeding groups

Macro-invertebrates collected in the two groups of sites have been clustered in six feeding groups (Fig. 3). Piercers, predators and scrapers were the most represented in the two groups.

These feeding groups represented respectively 33 %, 26% and 23% of the taxonomic richness in group 1 while in group 2they constituted respectively 26%, 23% and 22% of the recorded taxa. Yet, scrapers were the more abundant both in sites with macrophytes (79%) and in the sites without macrophytes (61%).

Table 2. Abundance and frequency of occurrence of the recorded taxa of macroinvertebrates at the two groups of sampling sites of the studied lakes of Yamoussoukro: Very frequent (FO > 50%), **frequent (25% ≤ FO < 50%), *rare occurrence (FO < 25%).

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Acheata				
Glossiphonia sp.	33	**	117	***
Haementeria sp.			2	*
Helobdella sp.	2	*	42	*
Hemiclepsis sp.			8	*
Oligocheata			4	*
Gasteropoda				
Bulinus forskalii	84	**	50	***
Bulinus globusus	16	*	47	**
Indoplanorbis exutus	836	***	535	***
Lanites varicus	22	**		
Lymnaea natalensis	686	***	463	***
Physa marmorata	6362	***	641	***
Pila africana	362	***	100	***
Biomphalaria pfeifferi	349	***	126	***
Bulinus troncatus	1	*	20	*
Gabiella africana	15	**	6	*
Melanoides tuberculata	1420	***	5497	***
Gordiacea				
Gordius sp.	8	*	2	*

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence

Insecta				
Coleoptera				
Amphiops sp.	417	***	242	***
Aulonogyrus sp.	29	*		
Cyphon sp.	19	*		
Donociasta sp.	10	*		
Heterhydrus senegalensis			2	*
Hydaticus sp.	264	***	85	**
Hydrobius sp.	59	***	92	***
Hydrocanthus sp.	4	*		
Hydrochara sp.	35	***	23	***
Laccophilus sp.			15	*
Pseudobagous longulus	52	**	6	*
Agabus sp.	7	*		
Cybister sp.	58	***	44	**
Dineutus sp.	2	*	2	*
Dytiscus sp.			3	*
Enochrus sp.	84	***	16	**
Gyrinus sp.	2	*		
Helodidae	2	*		

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Insecta				
Coleoptera				
Hydrovatus sp	169	***	31	***
Hydrocoptus sp.	12	*		
Hydrocyphon sp.	8	*		
Limnius sp.	49	**	19	**
Noterus sp.	6	*	2	*
Parasthetops sp.	7	*		
Spercheus sp.	1	*	8	*
Diptera				
Ablabesmya sp.	12	*	17	*
Ceratopogonidae	3	*		

Culicidae	56	***	129	***
Muscidae	6	*	2	*
Proclaclius sp.			4	*
Steriochironomus sp.			2	*
Stratiomyidae			6	*
Tabanidae	33	***	63	**
Xenochironomus sp.			16	**
Acenthocema sp.			4	*

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Insecta				
Diptera				
Chironomus sp.	478	***	913	***
Clinotanypus sp.			14	*
Cryptochironomus sp.	74	***	368	***
Leptoconops sp.	3	*		
Limonia tipulipes	2	*	1	*
Mochlonyx sp.			1	*
Polypedilium sp.	4	*	5	*
Psychodidae			2	*
Sciomizidae			2	*
Syrphidae	86	**	17	*
Ephemeroptera				
Adenophlebiodes sp.	18	*	10	*
Baetis sp.	346	***	298	***
Cloeon sp.	11	*		
Hemiptera				
Angilia sp.	2	*		

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Insecta				

Hemiptera				
Diplonychus sp.	535	***	391	***
Enithares sp.	35	*		
Eurymetra sp.	2	*		
Hydrocyrius sp.	20	*	10	*
Hydrometra sp.			4	*
Laccocoris sp.	4	*		
Laccotrephes sp.	2	*		
Mesovelia sp.			35	**
Micronecta sp.	2	*	10	*
Microvelia sp.	10	*		
Naucoris sp.	39	**	20	*
Anisops sp.	159	***	60	***
Corixini sp.	2	*		
Hydrovatus sp.	503	***	66	***
Limnogeton sp.	4	*	2	*
Limnogonus sp.	10	*	4	*
Normandia sp.	8	*		

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Insecta				
Hemiptera				
Ranatra sp.	20	**	13	**
Stenocorixa sp.	2	*		
Lepidoptera				
Elophila sp.	60	**	6	*
Odonata				
Aeshna sp.	2	*		
Brachythemis sp.			15	**
Bradinopyga sp.	11	*	6	*
Ceriagrion sp.	111	**	59	**
Chalcostephia sp.	4	*	4	*
Cordulgaster sp.			2	*
Diplacodes sp.	8	*		

Erythromma sp.			10	*
Orthetrum sp.	3	*		
Phaon sp.	4	*	14	*
Phyllomacromia sp.	54	*	9	*
Pseudagrion sp.	2	*	81	***

(continued)

Taxons	Group 1 (sites with macrophytes)		Group 2 (sites without macrophytes)	
	Abundance	Frequency of occurrence	Abundance	Frequency of occurrence
Insecta				
Odonata				
Sympetrum sp.			2	*
Tholymis sp.	4	*	2	*
Trithemis sp.	43	*	4	*
Urothemis sp.	7	*		
Trichoptera				
Diclonyclum sp.	23	*		
Dyschimus sp.	4	*		
Polycentropus sp.	5	*		
Stactobia sp.			6	*
Turbellaria				
Planaria sp.	2	*		
Taxonomic richness		84		76
Total abundance	11146		10928	

Similarities between sampling sites and indicator taxa

Sorensen similarity Index calculated to compare macro-invertebrate taxonomic composition in Yamoussoukro lakes indicated a low similarity (0.33) between group 1 and group 2.

Two taxa (families of Diptera) with significant indicator values (permutation test, $P < 0.05$) were recorded (Table 4). Samples collected in group 1 were mainly characterized by Tabanidae (Indval=0.774; p=0.007) while Culicidae (Indval=0.779; p=0.023) appeared as specific to group 2.

Discussion

Macro-invertebrates diversity and structure according to macrophyte presence or absence

Non-significant difference was observed in diversity measurement (taxonomic rarefied richness, Shannon-Weiner index and Pielou's Evenness Index) between the two groups of sites. Diversity and abundance of macro-invertebrate communities collected both under macrophytes and in open water were statistically identical. According to Walker *et al.* (2012) macrophytes can affect macro-invertebrates abundance but it causes no significant differences in macro-invertebrate species richness and diversity. This situation is probably due to the bad environmental conditions in studied lakes. Indeed Yamoussoukro lakes are affected by a modification of their water balance, due to hydrological and hydro-dynamical modifications, increased sedimentation and physicochemical pollutions (Kouamé *et al*., 2011). Because of pollution level in these aquatic systems, macrophyte influence on invertebrate community could not be perceptible.

Table 3. Proportions of very frequent taxa (***), frequent taxa (**) and rare taxa (*) in macroinvertebrates collected in group 1 (sites with macrophytes mats) and group 2 (sites without macrophytes) of the studied lakes of Yamoussoukro.

	Group 1	Group 2
Very frequent taxa	24.1%	24.68%
Frequent taxa	13.25%	15.58%
Rara taxa	62.65%	59.74%

However macro-invertebrates collected was relatively most abundant and most diversify under macrophyte beds (especially Gasteropoda and Insecta). This result shows that macrophytes play an important role in providing a stable habitat structure in the studied hydrosystems. Indeed, freshwater vegetations are home to a variety of macro-invertebrates belonging to Insecta and Mollusca (Habib and Yousuf, 2014). The complex structured plants support higher macro-invertebrate abundance and species thereby making plant morphology an important determinant in invertebrate distribution (Hansen *et al.,* 2010). According to Warfe and Barmuta, (2006), macrophytes are found to be better habitat for invertebrate fauna as these provide more number of microhabitats which increases the overall available niche space (Willis *et al*., 2005).

Table 4. Significant indicator taxa (IndVal, $P < 0.05$) for each group of sites: 1= sites with macrophytes mats; 2= sites without macrophytes.

Indicators taxa	Group of sites	Indval	Probability
Tabanidae	1	0.774	0.007
Culicidae	2	0.779	0,023

Moreover, Ephemeroptera and Trichoptera were most relatively abundant in sites with macrophytes mats. These organisms are indicative of less impacted aquatic ecosystems (Dickens and Grahams, 2002). They are sensitive to low concentration of dissolved oxygen (Stiers *et al*., 2011). Relative importance of Ephemeroptera and Trichoptera under macrophytes can be explained. Indeed, aquatic invertebrates find refuge from prevailing hypoxic conditions in the overlaying water by using the oxygen excluded from the roots of the macrophyte. This situation was observed by Kornijow *et al.* (2010) who reported greater density of invertebrates in the roots of the floating mats *Trapa natans* in the fresh water tidal Hudson River.

Bad environmental conditions in studied lakes

Physa marmorata and *Melanoides tuberculata* (Gasteropoda) were most abundant and very frequent (FO =100%) in each group of sites. Meanwhile, Trichoptera, indicator of good environmental conditions, were found as rare taxa in each group of sites. These results indicated high degree of pollution of Yamoussoukro lakes. Indeed, according to Kouamé *et al.* (2011), these lakes receive permanently important quantities of untreated urban wastewater and solid wastes. Besides, several studies (Ndifon and Ukoli, 1989; Bony *et al*., 2008)were shown that the genus *Physa* was usually met in ecosystems with high organic pollution level.

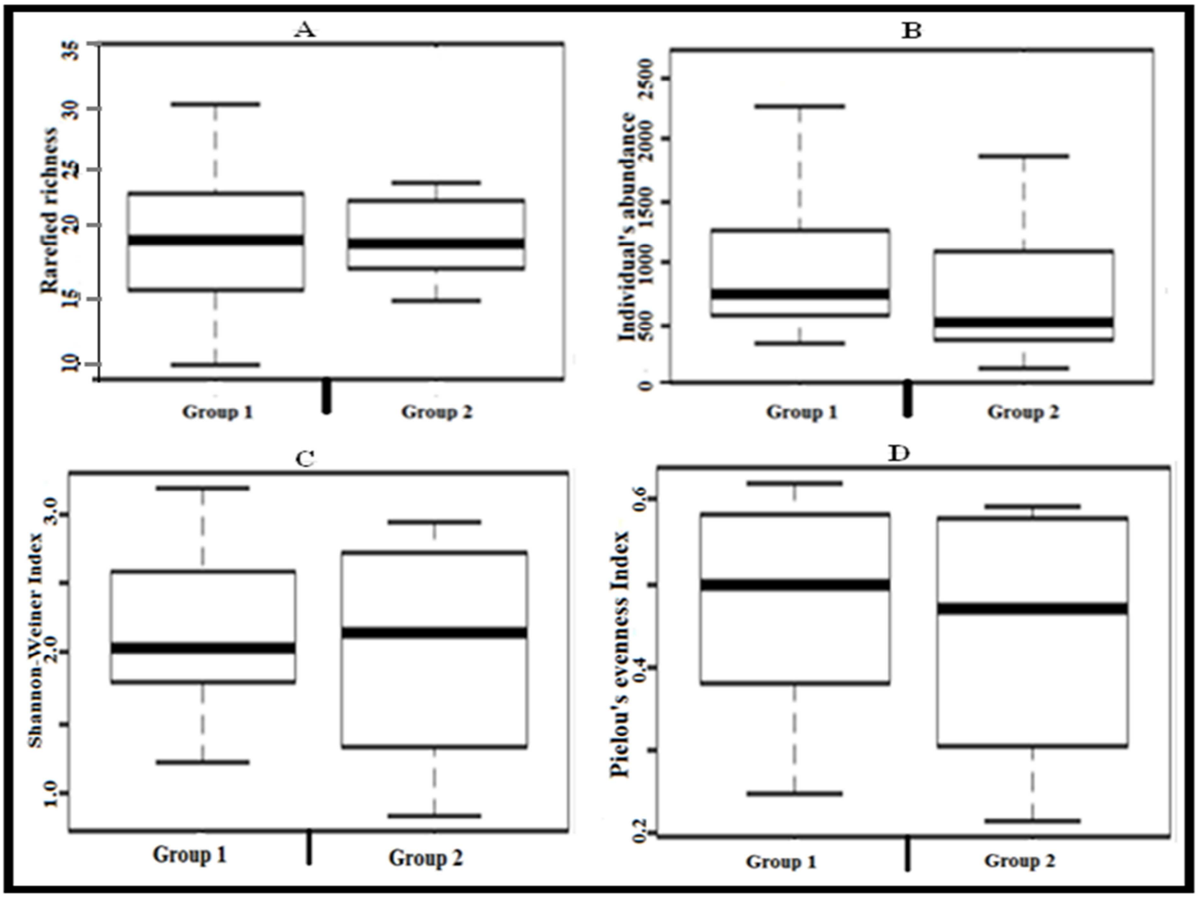

Fig. 2. Box-plots showing variations of rarefied richness (A), abundance (B), Shannon index (C) and Pielou's Evenness (D) between group 1 (sites with macrophytes mats) and group 2 (sites without macrophytes) of the studied lakes of Yamoussoukro.

Composition and structuration in feeding groups observed both in sites with macrophytes and in sites without macrophytes were similar. Scrapers were the most abundant in each group of sites. This feeding group was mainly represented by Gasteropoda which are great consumers of algae.

This result shown an important production of Algae in all the sites prospected due probably to great quantities of nutrients in wastewater discharged in Yamoussoukro urban lakes.

A low taxonomic similarity was observed between the two groups of sites. The indicator value analysis revealed that Tabanidae and Culicidae (Diptera) appeared as taxa associated with respectively group 1 (sites with macrophytes mats)and group 2 (sites without macrophytes). Because of their bad environmental conditions, Yamoussoukro aquatic systems constitute a favourable environment for Culicidae and Tabanidae which are frequently vectors of various disease agents (Thomson and Conor, 2000).

According to Kouamé *et al.* (2011), pollution of Yamoussoukro lakes caused increasing of malaria these last years.

This study showed that in urban lakes intensely polluted, macrophytes presence remains just a consequence of the pollution and cannot be used to explain any variation in macro invertebrates composition. Thus in this situation it's suitable to assess the pollution level in each site or in each lake before understanding and explaining difference in macrofauna communities between sampling sites.

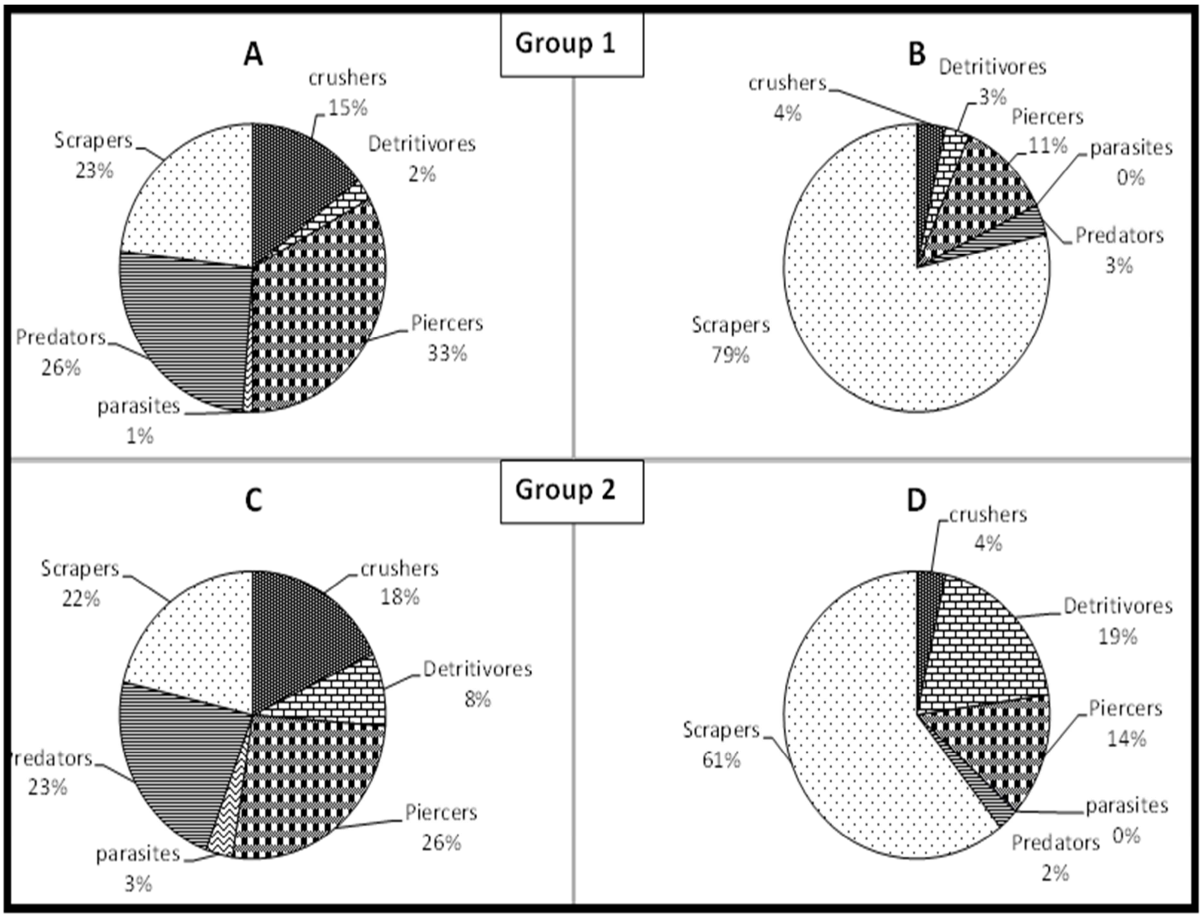

Fig. 3. Relative specific richness (A and C) and relative abundance (B and D) of macroinvertebrates feeding groups defined in sites with macrophytes mats (Group 1) and in sites without macrophytes (Group 2) in the studied lakes of Yamoussoukro.

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