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Mathieu Kobenan Kra
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Idrissa Adama Camara
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Edia Oi Edia
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Mexmin Koffi Konan
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Dramane Diomande
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Allassane Ouattara
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Correspondence
Mathieu Kobenan Kra
Laboratoire d'Environnement et de Biologie Aquatique (LEBA), UFR-Sciences et Gestion de l'Environnement (SGE), Universite Nangui Abrogoua (UNA), 02 BP 801, Abidjan 02, Côte d'Ivoire

Qualitative analysis of aquatic macroinvertebrates in lower comoe river (Côte d'Ivoire)

Mathieu Kobenan Kra, Idrissa Adama Camara, Edia Oi Edia, Mexmin Koffi Konan, Dramane Diomande and Allassane Ouattara

Abstract
This paper presents a study on aquatic macroinvertebrate communities in lower Comoe river belonging to Grand Bassam wetland (Côte d'Ivoire). Six sites (C1-C6) were sampled during eight campaigns from June 2014 to May 2017. At each site macroinvertebrates were collected using a Van Veen grab and kick-net (25 x 20 cm, 500 µm mesh size). Environmental variables were recorded also. Water was collected from each sampling site for nutrient (phosphorus, nitrate) analysis in laboratory. A total of 97 macroinvertebrate taxa belonging to 49 families, 15 orders and 08 classes were identified in the lower Comoe river. Insecta was the most representative class (70 taxa) followed by Gastropoda (14 taxa). The order of Coleoptera was the most diversified (20 taxa) followed by Odonata (15 taxa). The Shannon-Weawer index varied between 0.66 and 2.82 and the Pielou evenness index between 0.30 and 0.96. The highest values of the rarefied richness was observed in the C1 (06) and C2 (6.45) sites, which were less subject to the different anthropogenic pressures, whereas the lowest values were recorded in C5 (2.20), a site under pressure from pig farming and organic fertilizers. The Sorensen Similarity index varied from 35.44% to 43.37% and was higher between C1 and C2, which are very close sites. The rare taxa were the most numerous at the different sites. Association of the different indices shown that C1, located upriver is less impacted and C5 in downriver the most impacted site.
Among the environmental variables, only phosphorus is significantly higher in C5 than in other sites. The results showed that macroinvertebrates were more correlated with temperature, conductivity, dissolved oxygen, phosphorus, nitrate and pH.

Keywords: aquatic macroinvertebrates, community structure, grand-bassam wetland, comoe river, Côte d'Ivoire

1. Introduction
Aquatic macroinvertebrates are commonly used to assess the overall health status of aquatic ecosystems because of their sedentary life style, varied life cycle, wide diversity and variable tolerance to pollution and habitat degradation [1-4]. As a result, studies on their inventory and ecology are of paramount importance in the understanding of the functioning and management of natural systems on the one hand and in the assessment of the ecological health status of waterbodies on the other hand [5]. In addition, sampling of macroinvertebrates requires little effort and produces few adverse effects on the biotope [1, 6].
The Comoe watershed is a transboundary basin between three countries (Burkina Faso, Ghana and Côte d'Ivoire). In the southern part of Côte d'Ivoire, this watershed has many industrial plantations (bananas, palm trees, pineapples…) that require the use of fertilizers and pesticides [7]. According to these authors, plantations are generally located near waterbodies. These factors make the water resources of this area vulnerable to pollution. One of the main causes of degradation of the quality of aquatic ecosystems is the intensification of agricultural practices [6, 8]. Studies have shown that waterbodies are among the most threatened ecosystems in the world especially those in the tropics [9, 10]. Indeed, according to Barbour *et al*. (1999) [11], estimates of the biodiversity loss of tropical waterbodies are alarming. In order to achieve a synthetic and comprehensive verification of the extent of degradation of water quality, it is necessary to opt for biological monitoring which, according to Dion (2009) [12], is recognized as an essential component of monitoring programs of water quality. Unfortunately, except for the work of Sangaré (1991) [13] on aquatic macroinvertebrates associated with the roots of

pistia stratiotes, there are no data on macroinvertebrates in the lower Comoe river. The macroinvertebrates of these aquatic ecosystems are thus little known compared to those of other Ivorian's. This study aimed to: i) determine the composition and distribution of aquatic macroinvertebrates of the lower Comoe river, ii) assess the effect of environmental variables on the distribution of aquatic macroinvertebrates. The results obtained from this study would provide viable information which could be used to identify the impacts of pollution as well as the effectiveness of pollution control activities of the lower Comoe river which belongs to Grand Bassam wetland.

2. Materials and Methods

2.1 Study area and sampling sites

The study area includes the Grand-Bassam wetland which is located in the southeast of Côte d'Ivoire. This region has an average altitude of 90 m, its climate is subequatorial with an average annual temperature ranged between 25 °C to 33 °C. The rainfall varies from 1400 to 2500 mm/year and an annual rate of humidity about 80 to 90 % [14]. This climate is characterized by four seasons: two dry seasons (mid-July to mid-September and December to March) and two rainy seasons (April to mid-July and mid-September to mid-November) [15]. Six sampling sites were selected in lower Comoe river (C1 to C6) (Figure 1). These sites were sampled during eight sampling campaigns from June 2014 to May 2017. Table 1 summarizes the characteristics of these sampling sites.

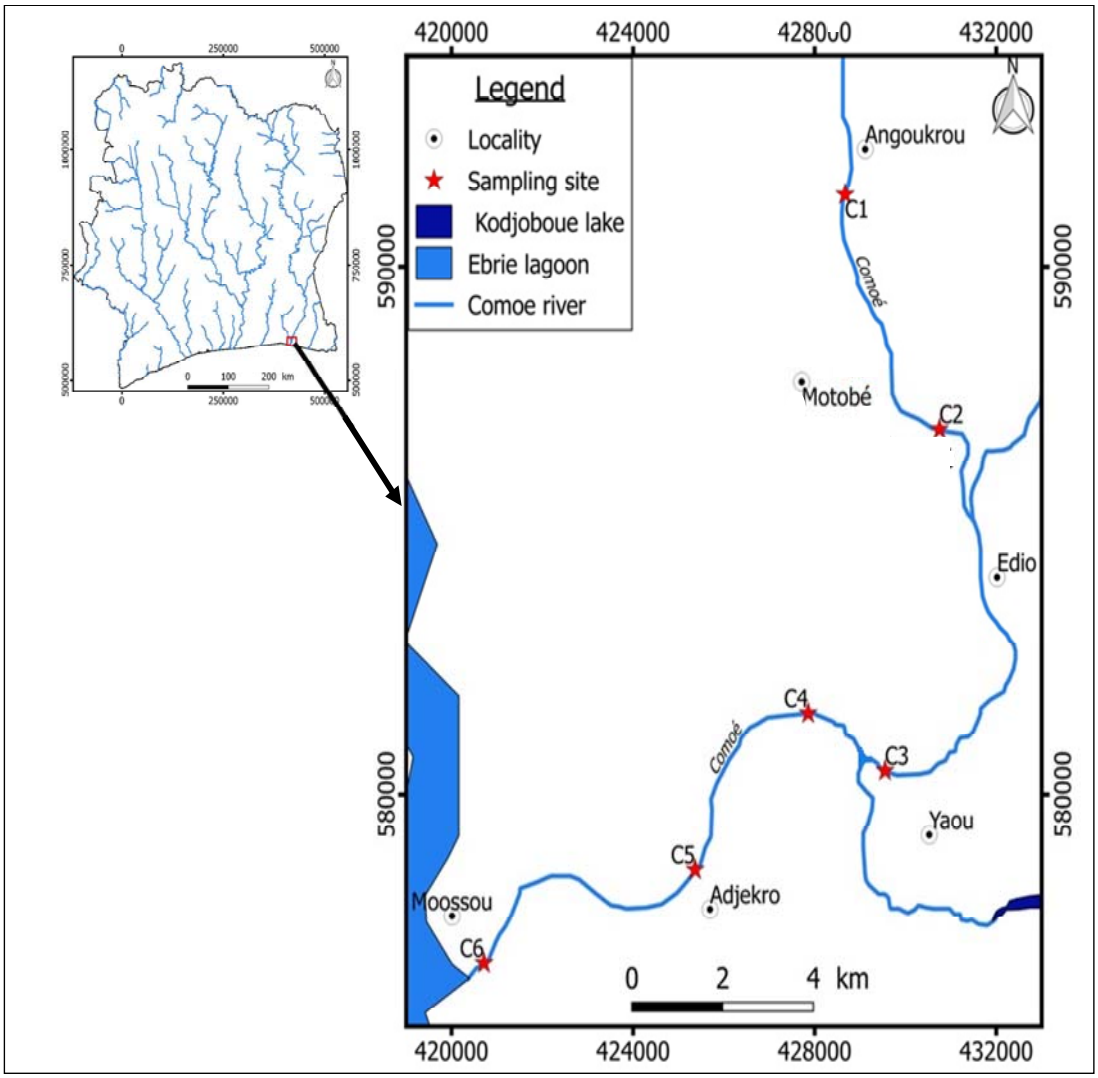

Fig 1: Location of the study area showing the six sampling sites of lower Comoe river (Côte d'Ivoire)

Table 1: Characteristics of the six study sampling sites in lower Comoe river (Côte d'Ivoire)

Sampling Sites	Geographical positions (UTM)		Land use	Canopy (%)
	X	Y		
C1	428687	591355	Cocoa, rubber tree and banana plantations	5
C2	430759	586858	Village, cocoa and rubber tree plantations	5
C3	429565	580382	Village, garbage dump, cocoa and rubber tree plantations	0
C4	427850	581464	Housing, palm nurseries and Cocoa plantations	0
C5	425356	578530	Housing, organic fertilizer plant, pigsty, rubber tree and coconut plantations	0
C6	420693	576758	Bridge, vegetable crops	0

2.2 Data collection

Aquatic macroinvertebrates were sampled at the sites during the eight sampling campaigns with van Veen grab and a kick-net (25 x 20 cm, 500 µm mesh size).

The fauna of the native vegetation covering the banks of the river and aquatic macroinvertebrates associated with *Eichhornia crassipes* were harvested using the kick-net. Corcerning the van Veen grab, it was used to sample macroinvertebrates in the sediments.

In the laboratory, specimens were sorted and identified to the lowest possible taxonomic level using a stereomicroscope Olympus SZ (40× magnification) and a series of identification keys [16-22]. The two samples (1 by grab and 1 by kick-net) at each point and each campaign were pooled for analysis. In addition, temperature, pH, conductivity and dissolved oxygen were determined directly at the same sampling site with a portable multi-parameter (HANNA), water transparency was determined with a Secchi disc. Water was also collected with bottle of 1L at each sampling site for nutrients (phosphorus and nitrate) analysis in the laboratory using Rodier methods [23].

2.3 Data analysis

In order to evaluate the structure of macroinvertebrate communities, Shannon-Weaver diversity index and Pielou evenness index were calculated. Taxonomic richness was rarefied in each site per sampling period. Precisely, rarefied richness was used to avoid any bias related to differences in abundances between samples [24]. The rarefaction was applied to the total taxonomic richness per site using the lowest abundance (71 individuals for this study) found in all sites as the target number of individuals [25]. The Sorensen similarity index was used to evaluate the similarity of macroinvertebrate communities between sites.

Before performing comparison analyses, data normality was checked using Shapiro test. Given the biotic and environment data distribution follow non-normal distribution ($P>0.05$), the non parametric test of Kruskal-Wallis was performed to compare data between sampling sites. When Kruskal-Wallis test is significant, Mann-Whitney test was used for pairwise comparison. The significance threshold was $p = 0.05$.

The occurrence percentage (FO) was calculated using the following formula: $FO = (Ni/Nts)\times100$, with Ni = number of samples containing a given species i, and Nts = total number of samples collected. The FO was used to classify species following Dajoz (2000) [26]: FO>50: very frequent species; 25<FO ≤50: frequent species; FO≤25: rare species.

Canonical Correspondence Analysis (CCA) was used to assess relationships between macroinvertebrate distribution and environmental variables. A Monte Carlo permutation test was performed to assess the statistical significance of the environment variables and the full model to arrive at the significance of the first two axes. The environment variables used were temperature, conductivity, dissolved oxygen, transparency, pH, nutrients (phosphorus and nitrate). Taxa of macroinvertebrates representing at least twenty percent of occurrence were retained for this analysis. Analyses were conducted using the R package.

3. Results

3.1 Environment variables

The table 2 shows the variations of environmental variables measured in the six studied sites.

Temperature ranged from 26.2°C (C1) to 33°C (C2). Conductivity varied between 34 µS/cm (C5) and 127 µS/cm (C6). The dissolved oxygen variation was situated between 0.45 mg/L (C4) and 61 mg/L (C4). The water transparency of the sites varied from 8 cm (C3) to 137 cm (C6). Concerning the pH, it varied from 6.49 (C4) to 7.9 (C6). Regarding the Phosphorus and nitrate, their values were low, varied from 0.01 mg/L (C1) to 0.58 mg/L (C3) and from 0.1 mg/L (C6) to 2.65 mg/L (C5) respectively.

Analysis showed significant differences of this parameter between this site and other sites (C1, C2, C3, C4 and C6) (Mann-Whitney, $p<0.05$).

Table 2: Environmental variables measured at six sampling sites of lower Comoe river (Côte d'Ivoire).

Parameters	C1	C2	C3	C4	C5	C6
Temperature (°C)	28.93^{a} (26.2-32.3)	28.94^{a} (26.7-33)	28.66^{a} (27.1-32.6)	29.01^{a} (27-31.8)	28.48^{a}(27.1-32.3)	28.35^{a} (26.8-31.1)
Conductivity (µS/cm)	76.05^{a} (36-116.9)	80.04^{a} (36-118.9)	76.41^{a} (37-121.6)	69.91^{a} (37-116.2)	78.03^{a} (34-121)	85.22^{a} (36-127)
Dissolved oxygen (mg/L)	6.24^{a} (0.9-10.11)	6.17^{a} (2.04-8.11)	4.39^{a} (2.14-7.73)	4.64^{a} (0.45-61)	4.6^{a} (1.01-7.12)	4.26^{a} (1-8.98)
Transparency (cm)	27^{a} (17-73)	27.50^{a} (16-91)	32.50^{a} (8-105)	31^{a} (13-87)	35^{a} (10-128)	36.57^{a} (11-137)
pH	6.98^{a} (6.69-7.6)	7.09^{a} (6.65-7.7)	6.85^{a} (6.5-7.3)	6.89^{a} (6.49-7.5)	7.11^{a} (6.57-7.5)	7.02^{a} (6.67-7.9)
Phosphorus (mg/L)	0.09^{a} (0.01-0.14)	0.09^{a} (0.018-0.18)	0.07^{a} (0.017-0.58)	0.10^{a} (0.035-0.13)	0.19^{b} (0.06-0.3)	0.10^{a} (0.06-0.23)
Nitrate (mg/L)	1.29^{a} (0.3-1.77)	0.76^{a} (0.2-1.71)	0.81^{a} (0.2-1.54)	0.81^{a} (0.2-1.77)	0.49^{a} (0.1-2.65)	0.50^{a} (0.1-.77)

Note: values are median (minimum and maximum are in parentheses). Different superscript letters (a, b) in a row show significant differences (Mann-Whitney, $p<0.05$) between sites.

3.2 Composition and distribution of macroinvertebrates

During this study, 97 taxa of aquatic macroinvertebrates belonging to 49 Families, 15 Orders and 08 Classes. The most representative group were Insecta (70 taxa) and Gasteropoda with 14 taxa (Table 4). Coleoptera was the most diversified order representing 20 taxa, followed by Odonata (15 taxa), Basomatophora (11 taxa) and Diptera (10 taxa). Libellulidae (Odonata) was the most represented family (10.31% of the taxa), followed by Chironomidae (Diptera) and Dytiscidae (Coleoptera) with 5.15% each. Only one species of freshwater crab was identified (*Uca tengeri*).

3.3 Diversity indices

The Shannon-Weaver index revealed that most of the study sites presented high diversity values (median >1.7). The lowest diversity value was recorded at C5 (0.66), whereas the highest value was observed at C1 (2.82). In general, the Shannon-Weaver index is greater than 2 in 50% of the samples.

The Pielou's Evenness Index evolution is similar to Shannon-Weaver index with the lowest value in site C5 (0.37).

Concerning the rarefied richness, it varied from 2.20 to 6.45 with the lowest in site C5. The highest values of rarefied

richness correspond to sites C1 and C2.

Excepted to the Shannon-Weaver index and Pielou's Evenness Index, there were no significant differences ($p< 0.05$) between sites in any of the diversity indices, as evidenced by the Mann-Whitney (Figure 2).

The Sorensen similarity index varies from 35.44% (C3-C5) to 43.37% (C1-C2), it showed that the sites are relatively similar (Table 3).

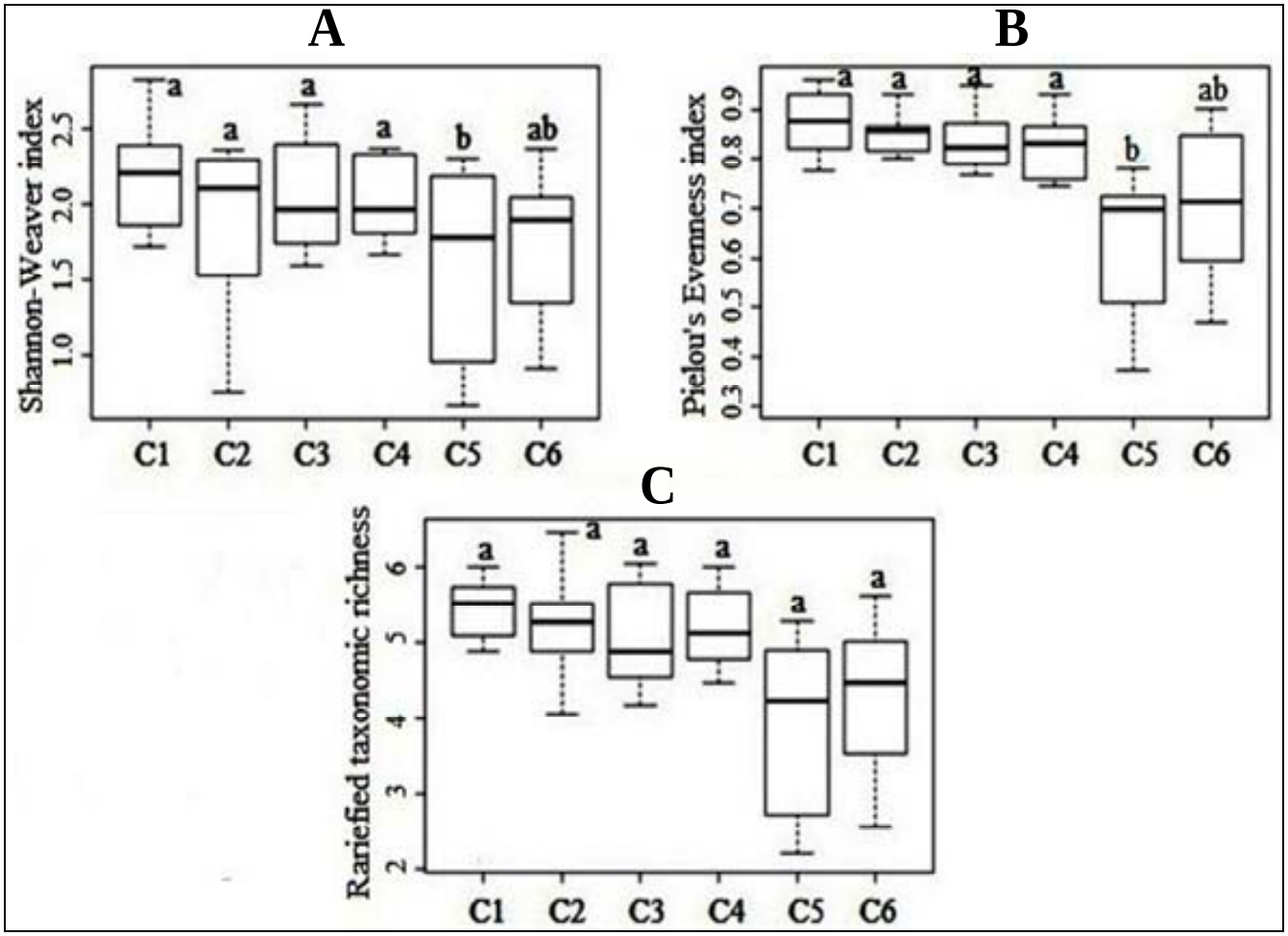

Fig 2. Box-plots showing variation of Shannon-Weaver index (A), Pielou's Evenness index (B) and Rariefed taxonomic richness of lower Comoe river (C1-C6). Different letters (a and b) on box-plots denote significant differences between them (Mann-Whitney, $p<0.05$)

Table 3. Values of Sorensen similarity index between the six sampling sites (C1-C6) of lower Comoe river (Côte d'Ivoire)

	C1	C2	C3	C4	C5	C6
C1		43.37	39.50	39.50	35.66	37.90
C2			40.93	40.00	39.34	40.67
C3				40.00	37.20	35.44
C4					39.79	41.08
C5						41.66
C6						

3.4 Frequency of occurrence

Table 5 shows the percentages of the very common, frequent and rare taxa at the six sites. The percentages of very common taxa vary between 15.38 % to 20.40 %. Those of frequent taxa varied between 24.49 % to 33.33 %. Regarding rare taxa, they are the most numerous at all sites with percentages ranging from 47.62% to 60.61%.

Twenty taxa were common to the six sites. Indeed, nine (*Macrobrachium* sp., *Cloeon* sp., *Caenis* sp., *Pseudagrion* sp., *Macrodiplax cora*, *Pseudobagous Longulus*, *Polypedilum* sp., *Theodoxus* sp., *Corbula trigona)* had a high occurrence (FO≥50).

Table 4: List of the macroinvertebrates taxa found in the six sites of lower Comoe river (Côte d'Ivoire).

				Sampling sites					
Class	**Orders**	**Famillies**	**Taxa**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Achaeta								*	
Polychaeta							*		
Oligochaeta					**	*	**	*	**
Malacostraca	**Amphipoda**	Gammaridae	*Gammarus* sp.	*	*			**	**
	Decapoda	Palaemonidae	*Macrobrachium felicinum*			*			
			Macrobrachium vollenovenii	*	**	*	*	**	*
			Macrobrachium sp.	***	**	***	***	***	***
			Macrobrachium macrobrachion						*
		Potamonautidae	*Potamonautes clarus*			*			
		Ocypodidae	*Uca tangeri*		**	**	**	**	
Arachnida	**Hydracarina**				*	*	*		
Insecta	**Ephemeroptera**	Baetidae	*Baetis* sp.	*	**	*	**	**	*
			Afrobaetodes sp.			*			
			Cloeon sp.	***	***	**	***	***	***
			Pseudocleon sp.		*				*
		Caenidae	*Caenis* sp.	***	**	**	***	***	**
		Ephemerellidae	*Ephemerella* sp.				*	*	
		Heptageniidae	*Epeorus* sp.					*	
			Notonurus sp.		*				
			Ecdyonurus sp.					*	*
		Leptophlebiidae	*Adenophlebiodes* sp.				**	*	*
	Odonata	Coenagrionidae	*Ceriagrion* sp.	*		*		*	*
			Coenagrion galbrum			*		*	
			Pseudagrion sp.	***	***	**	***	***	***
		Libellulibidae	*Chalcostephia* sp.		*	*			*
			Crocothemis sp.	**	*	*	**	*	*
			Diplacodes lefebvrii				*	*	*
			Libellula sp.		*		*	*	*
			Macrodiplax cora	**	***	***	***	***	***
			Pantala flavescens	**	*	*	**		
			Trithemis dorsalis			**	*	**	*
			Urothemis sp.				*		**
			Zyxomma petiolatum					*	
			Zygonyx torridae		*			*	*
		Lestidae	*Lestes plagiatus*					*	
		Synlestidae	*Chlorolestes fasciatus*		*	*		*	
	Heteroptera	Belostomatidae	*Diplonychus* sp.	**	*	*		***	**
		Corixidae	*Micronecta* sp.				*		
		Gerridae	*Eurymetra* sp.	**	**	**	*		*
			Limnogonus sp.		*			*	*
			Rhagadotarsus sp.	*	*		*		**

Table 4 (Continued).

				Sampling sites					
Class	**Orders**	**Famillies**	**Taxa**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Insecta	**Heteroptera**	Naucoridae	*Laccocoris* sp.				*		
			Naucoris sp.	*			*		
		Nepidae	*Ranatra linearis*		*		*		
		Notonectidae	*Notonecta* sp.						*
			Anisops						*
		Veliidae	*Microvelia* sp.	**	*	*	**	**	**
	Trichoptera	Ecnomidae	*Ecnomus* sp.	*	*			*	
		Hydropsychidae	*Polymorphanisus* sp.			*		*	
		Leptoceridae	*Trianodes* sp.	*	*	*			
		Ecnomidae	*Ecnomus* sp.						
	Coleoptera	Curculionidae	*Cytobagous* sp.					*	
			Pseudobagous Longulus	***	***	***	***	***	***
		Dytiscidae	*Bidessus* sp.						*
			Hydaticus sp.	**	*	**	*	*	*
			Hydrovatus sp.	*	**	***	**	***	***
			Hyphydrus						*
			Laccophilus sp.	**		*	*		*
		Helodidae	*Hydrocyphon* sp.		*				
		Elmidae	*Elmis sp.*	*					
			Limnius sp.				*	**	
			Macronychus sp.					*	
			Potamodytes sp.			*	*	*	
		Gyrinidae	*Orectogyrus* sp.				*		*
		Haliplidae	*Haliplus* sp.				*		*
		Hydrochidae	*Hydrochus* sp.					*	
		Hydrophilidae	*Amphiops* sp.	*		**	*		
			Enochrus sp.		**			**	**
			Hydrobius sp.					*	
			Laccobius sp.				*	*	*
		Noteridae	*Hydrocanthus* sp.					*	
	Diptera	Chironomidae	*Ablabesmyia* sp.	*	*		*	**	**
			Chironomus sp.		*		*	**	**
			Cryptochironomus sp.				*	*	
			Polypedilum deletum	**	**	***	**	**	***
			Stictochironomus sp.	*	*		*	*	**
		Athericidae	*Atherix* sp.	*	*				*
		Ceratopogonidae	*Culicoides* sp.	*	**	*	*		
		Culicidae	*Culex* sp.	*	*	*	*		
		Dixidae	*Dixa* sp.	*	*				
		Rhagionidae	*Rhagionidae*		*	*	*	**	*
Gasteropoda	**Basomatophora**	Ampullarridae	*Lanistes varicus*	**	***	*	*	*	
			Pila sp.			*	*		
		Bithiyniidae	*Gabbiella* sp.		*		**	*	*
			Gabbiella africana	**	*	**			
		Lymnaeidae	*Lymnaea natalensis*	**	***	**	**	*	**
		Thiaridae	*Melanoides tuberculata*	***	*	**	**	**	*
			Pachymelania byronensis	**	**	***		**	
			Pachymelania fusca			***	**	***	***
			Pachymelania fusca quadriseriata	*			*	***	**
		Planorbidae	*Biomphalaria pfeifferi*	*	*	*	**	**	**
			Indoplanorbis exustus	***	***	***	***	**	**
	Archeagasteropoda	Neritidae	*Neritina* sp.			*			
			Neripteron sp.	*	*	**	*		
			Theodoxus sp.	***	**	***	*	**	*
Bivalve	**Eulamellibranchia**	Corbulidae	*Corbula trigona*	**	***	***	**	***	***
			Iphigenia delesserti			*			
	Taxonomic richness		97	42	52	49	56	59	53

*** Very frequent (%OF>50); ** frequent (25<%OF ≤50);* rare (%OF≤25)

Table 5: Proportions of aquatic macroinvertebrates very frequent (***), frequent (**) and rare (*) at the different sampling sites of the lower Comoe river (Côte d'Ivoire).

Sites	Very frequent (%)	Frequent (%)	Rare (%)
C1	19.05	33.33	**47.62**
C2	15.38	25	**59.62**
C3	20.40	24.49	**55.10**
C4	12.50	26.79	**60.71**
C5	18.65	28.81	**52.54**
C6	16.98	28.30	**54.72**

3.5 Correlation between macroinvertebrate community and environment variables

The results of the Canonical Correspondence Analysis (CCA) showed that the correlation between environmental variables and macroinvertebrate taxa was mainly explained by the first two axes (68, 25%) of total variance (Figure 3).

The temperature (T) was positively correlated with the first axis, however, conductivity (CND), pH and phosphorus (PO4) were negatively correlated with this axis. Corcerning the second axis, it was positively correlated with dissolved oxygen (OD) and negatively correlated with nitrate (NO3).

C1 and C3 were characterized by high values of temperature and low values of conductivity, pH and phosphorus. These sites were associated with the presence of *Chironomus* sp., *Polypedilum deletum*, *Pseudagrion* sp., *Gabbiella africana* and *Caenis* sp. The site C2 was characterized by high values of nitrates and the presence of *Ecnomus* sp. and *Atherix* sp. . The site C4 was associated with the presence of *Pachymelania fusca*, *Potamodytes* sp. and high values of dissolved oxygen. C5 and C6, were characteristic of high values of conductivity, pH, phosphorus and the presence of taxa like *Stictochironomus* sp. ,*Enochrus* sp. and *Gabbiella* sp..

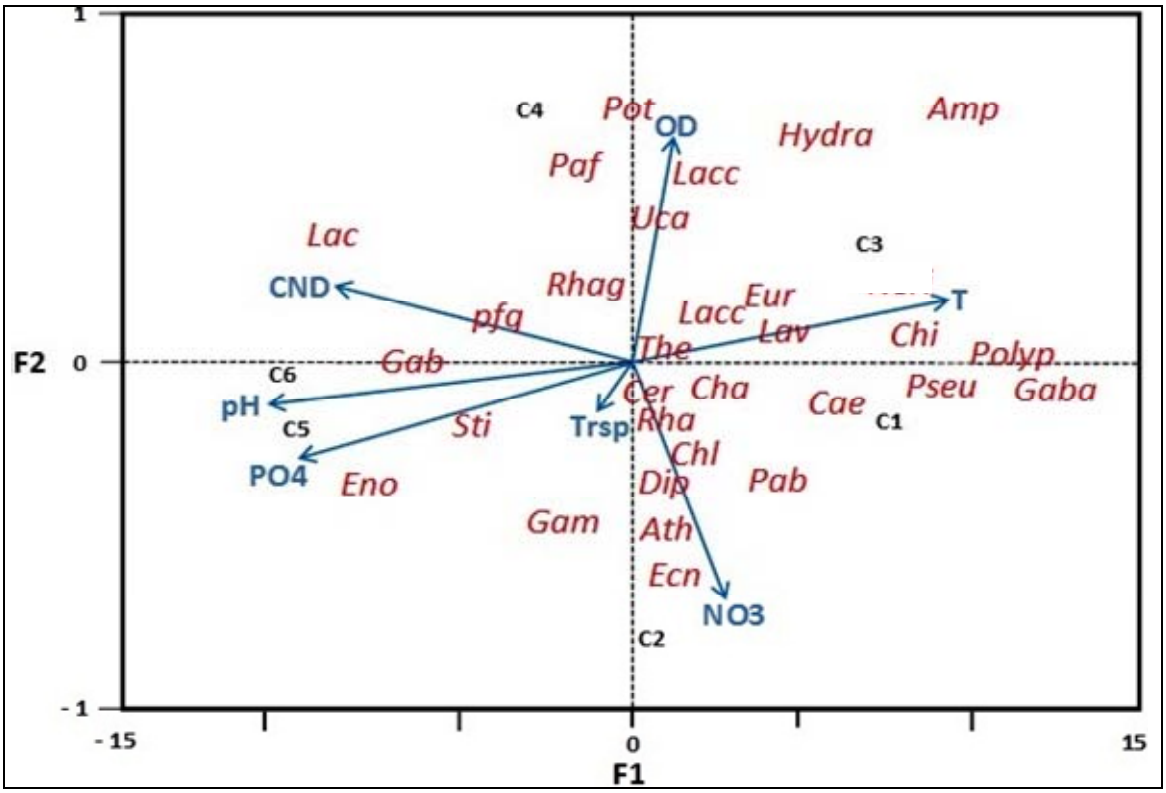

Fig 3: Canonical correspondence analysis showing taxa and sampling sites in relation to environmental variables in lower Comoe river (Côte d'Ivoire)

Sample codes :C1-C6 from lower Comoe river ;Taxa codes: Gam=*Gammarus* sp., Uca=*Uca tangeri*, Hydra=Hydrachnellea, Baet=*Baetis* sp., Cae=*Caenis* sp., Cer=*Ceriagrion* sp., Pseu=*Pseudagrion* sp., Cha=*Chalcostephia* sp, Chl=*Chlorolestes fasciatus*, Dip=*Diplonychus* sp., Eur=*Eurymetra* sp., Rha=*Rhagadotarsus* sp., Ecn=*Ecnomus* sp., Lacc=*Laccophilus* sp., Pot=*Potamodytes* sp., Amp=*Amphiops* sp., Eno=*Enochrus* sp., Lac=*Laccobius* sp., Chi=*Chironomus* sp., Polyp=*Polypedilum deletum*, Sti=*Stictochironomus* sp., Ath=*Atherix* sp., Rhag=Rhagionidae, Lav=*Lanites varicus*, Gab=*Gabbiella* sp., Gaba=*Gabbiella africana*, Pab=*Pachymelania byronensis*, Paf=*Pachymelania fusca*, Pfq=*Pachymelania fusca quadriseriata*, The=*Theodoxus* sp. ;Environment variables: T=temperature, CND=conductivity, Trsp= transparency, DO=dissolved oxygen, PO4=phosphorus, NO3=nitrate.

4. Discussion

Analysis of the physical and chemical parameters of the lower Comoe River reveals that the parameters (temperature, conductivity, dissolved oxygen, transparency, pH and nitrate) show no significant variation between sites. However, phosphorus is significantly higher in C5 than in the other sites. This relative high concentration of phosphorus in C5 would be linked to the effluents resulting from numerous

human activities, namely the intensification of pig farming and the organic fertilizer plant. C5 would therefore be the site most subject to anthropogenic pressures.

The low values of nutrient (phosphorus and nitrate) are due to the fact that waters receive very little effluent or simply dilution of effluents. Lower pH was related to the mineralization of organic particles [27]. Similar results were obtained by Simmou *et al*. (2015) [28].

The temperature range obtained in this study shows that the water remains relatively hot. This range is close to those observed in most Ivorian hydrosystems [28 -32], but remains higher. The high value of the temperature is related to the fact that most sites were devoid of canopy.

The high values of transparency in C5 and C6 is due to the sedimentation of the particles in suspension related to low flow of water.

The number of macroinvertebrates taxa found in this study (97) is higher than one found in Bia river (81 taxa) and Agneby river (50 taxa) ([33], [30]), and lower than that found in Banco river with 132 taxa [32]. It is also lower than that found in study of Simmou *et al*., 2015 [28]. This difference in taxonomic richness between studies would probably be related to the sampling method, the types of habitats surveyed, the sampling equipment used and the size of the sampled hydrosystems. Of the taxa collected in this study, aquatic insects were the most diversified, corresponding to 70 of the 97 taxa sampled. Insecta represent one of the most important groups of freshwater invertebrates especially due to its diversity [34]. The faunistic composition of this study is close to those of african's freshwaters. Among insects, Coleoptera are best represented with 25 taxa. The preponderance of the Coleoptera is explained by the fact that they are the only holometabolous insects to occur in both the imaginal and larval form in aquatic environments. They colonize various habitats when conditions become hostile for other species decreasing interspecific competition [35]. Our results are in accordance with those quoted by Diomandé *et al*., 2009, Foto *et al*., 2011, Simmou *et al*., 2015 and Kamb *et al*., 2016 [27, 30, 36, 37].

Many taxa of Ephemeroptera and Trichoptera constantly collected from several sites, with an occurrence between 25% and 50% indicate a low degradation of these waters. Indeed, according to Arimoro *et al*. (2007) [38], their presence in a hydrosystem is indicative of good water quality.

The percentage of taxa very frequent was high at sites C1 and C3. These sites would therefore provide a relatively favourable environment for a large number of taxa. In the adverse environmental conditions, four types of reactions are noted, namely the loss of taxa sensitive to slight pollution, a gradual reduction in the density of certain taxa and their disappearance on highly polluted sites [39], this justifies the high proportion of rare taxa in all sites of the lower Comoe river.

The Shannon-Weaver index calculated ranging between 0.66 (C5) and 2.82 (C1). These results show that the waters had good ecological health. The Pielou's Evenness index calculated for the waters varying from 0.30 to 0.96. These results show that the distribution of benthic macroinvertebrates taxa is more or less balanced in the lower Comoe River. Concerning the rarefied richness, it shows that in absence of any bias in the samples, C1 and C2 are the richest in taxa and therefore the least impacted. Among the three diversity metrics, the Pielou's Evenness Index and Shannon-Weaver index show a significant difference at C5. At this site, these indices are significantly lower, thus confirming the influence of anthropogenic pressure, namely the intensification of pig farming and the organic fertilizer plant.

The highest value of Sorensen similarity index is noted between C1 and C2. This strong similarity between these two sites is explained by their proximity, which makes them subject to almost the same conditions. Association of different indices studied, revealed that most of the sites of the lower Comoe river have a good ecological status with C1 being the least disturbed station. However C5 is the most impacted because of the various anthropogenic pressures.

The canonical correlation analysis showed the influence of environmental factors on the macroinvertebrate community, as environment variables are frenquently used to explain variation in macroinvertebrates communities [40-41]. Temperature (T), conductivity (CND), dissolved oxygen (OD), phosphorus (PO4), nitrate (NO3) and pH were shown as the most important environmental variables which explain macroinvertebrate distribution along lower Comoe river. Diomandé *et al.* (2009) [31] in Bia River, reported significant relationships between aquatic organisms distribution and environmental factors such as temperature, dissolved oxygen, nitrate and pH.

5. Conclusion

This study supplemented information on the structure of macroinvertebrate communities, contributing to narrowing the gap in studies of this nature in the Comoe lower basin. During this study, 97 taxa belonging to 49 Families, 15 Orders and 08 Class were recorded. The most representative group were insects (70 taxa). Distribution of aquatic macroinvertebrates of the lower Comoe River was best explained by temperature, conductivity, dissolved oxygen, phosphorus, nitrate and pH. The different indices studied, revealed that the ecological state is less alarming. It is therefore necessary to protect this wetland.

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