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ORIGINAL ARTICLE

Distribution of Aquatic Insects among Four Costal River Habitats (Côte d'Ivoire, West-Africa)

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ABSTRACT
We analysed aquatic insect distribution among four coastal river habitats of southeast Ivory Coast. In each river, two sites were sampled: one upstream and one downstream. In the eight sites, aquatic insects were randomly sampled eight times (i.e. four during the rainy season and four during the dry season) between July 2003 and March 2005. The basic criteria for classifying sampling sites by both the Principal Component Analysis and the hierarchical cluster analysis are mainly the nature of the waterbed substrate and the mineralization of the water. Overall, 115 taxa belonging to 51 families and ten orders were recorded. The richest taxon diversity was observed for Diptera and Ephemeroptera. The Indval method revealed that the most mineralized sites were characterised mostly by dipterans. However, the indicator taxa of weakly mineralized sites are mainly ephemeropterans. Taxa such as Laccophilus sp., Ablabesmyia sp., Ceratopogon sp., Cryptochironomus sp., Labiobaetis gambiae, Procloeon sylvicola and Nanocladius sp. were generalist in respect to the substrate nature. Riolus sp. Perla sp., Choroterpes sp., Cloeon sp. and Ephoron sp. were specialists of sandy substrate. Compsoneuria njalensis was characteristic habitats whose bottom is muddy.
***Keyword:** Aquatic insects, distribution, habitats, coastal rivers, West Africa.*

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INTRODUCTION

The distribution of aquatic organisms relative to their habitat is of central importance to ecology [1]. Moreover, stream-dwelling macroinvertebrates are generally thought to be distributed according to environmental factors [2]. Furthermore, according to [1], numerous studies have suggested that variability in physical factors, chemical factors and biological factors provide diverse habitats, and species specific habitat association of organisms in response to environmental variability has been found. Thus, the nature of this distribution provides an initial insight into the types of ecological processes that regulate populations and assemblages. For example, the distribution of macroinvertebrates among stream habitats reflects, to some degree, the distribution of benthic resources (e.g. food, oxygen, predators), and provides information about how communities might respond to changes in environmental parameters such as increased sedimentation and changes in flow [3]. Despite its importance, few studies have been published on the distribution of benthic macroinvertebrates among stream habitats for tropical systems.
Particularly, in Côte d'Ivoire, substantial literatures on aquatic macroinvertebrates are available (e.g. [4-9]). Only a few studies have been devoted to the distribution of benthic macroinvertebrates among stream habitats [4, 8, 9].
In this work, we focussed on four small coastal streams in the southeast of Côte d'Ivoire. Despite the lack of ecological information on these systems, they play an important role for human populations. These streams are used for domestic activities (drinking, cooking, bathing, fisheries...). It is therefore important to preserve these water resources and maintain the biotic integrity of these ecosystems. Such management requires basic knowledge such as the distribution of the aquatic communities among stream habitats [10].
This study aimed to: i) characterize the sampling sites according to environmental variables in order to establish a typology of these sites, ii) describe the composition of aquatic insects at different stations of the studied rivers and iii) identify indicator taxa of different clusters obtained from the sites typology.

MATERIAL AND METHODS

Study area

The study was undertaken in four coastal rivers located in the South-East of Ivory Coast (Figure 1): Soumié, Eholié, Noé, and Ehania rivers. Soumié River is a tributary of Bia River. Its drainage area covers 395 km2**.** It is 41 km in length with a mean annual flow of 11.76 m3.s-1 and a slope of 3.31 m.km-1. The river Eholié with a slope of 2.96 m.km-1 and a length of 35 km, covers a catchment area of 373 km^2 and flows into the Aby lagoon with an annual mean flow of 11.4 m3.s-1. The rivers Noé and Ehania are both tributaries of Tanoé river. Their catchments cover respectively 238 and 585 km2. With a length of 70 km, Ehania River has a general slope of 2.36 m.km-1 and an annual mean flow of 15.74 m3.s-1. The River Noé, which is just 30 km in length, has a slope of 1.45 m.km-1 and flows into the Tanoé with an annual mean flow of 9.56 m3.s-1.

In each of these coastal rivers, two sampling sites were retained: one upstream and the other downstream (Figure 1). Table 1 summarizes the environmental characteristics of these sites.

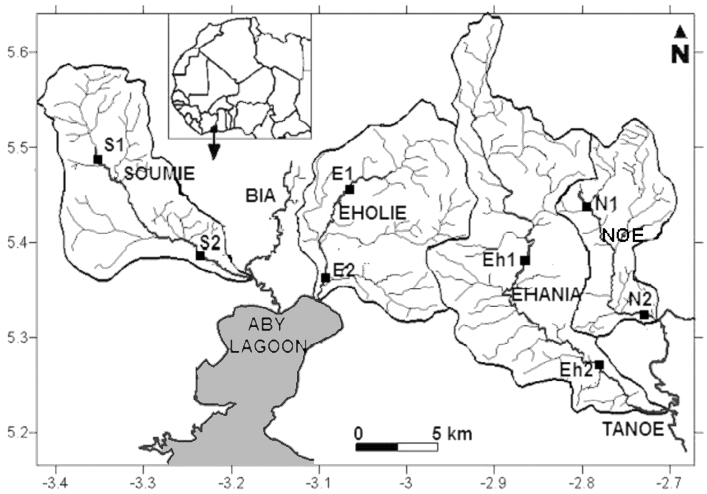

Figure 1: Location of the study area showing the four studied rivers. Dot marks indicate the sampling points on the four rivers. In station names, the letter indicates the river name (S: Soumié; E: Eholié; Eh: Ehania; N: Noé) and the number shows the station position on the river (1 = upstream and 2 = downstream).

Table 1: Characteristics of the eight study sites in four coastal rivers of Ivory Coast

	Soumié River		Eholié River		Ehania River		Noé River	
	Site S1	Site S2	Site E1	Site E2	Site Eh1	Site Eh2	Site N1	Site N2
Geographical positions	05° 29' N 03° 22' W	05° 24' N 03° 17' W	05° 28' N 03° 08' W	05° 23' N 03° 08' W	05° 24' N 02° 55' W	05° 17' N 02° 50' W	05° 28' N 02° 51' W	05° 18' N 02° 46' W
Width (m)	14.34	16.92	22.28	22.18	15.58	29.93	11.11	15
Depth (m)	0.84	1.41	1.27	1.88	1.44	2.29	0.69	2.38
Current velocity (m.s-1)	0.48	0.42	0.37	0.26	0.36	0.26	0.39	0.21
Predominant substratum	Gravel/sand	Sand	Clay/mud	Sand	Clay/mud	Sand	Clay/mud	Gravel
Population density	Very low	Very low	Very low	High	Low	Very low	Low	High
Adjacent land use	Cultivated	Cultivated	Riparian forest	Housing Cultivated	Housing Cultivated	Riparian forest	Housing Cultivated	Housing

Very low: a few dispersed houses along the banks, Low: discontinuous built-up areas along the banks, High: continuous built-up areas.

Aquatic insect and environmental variable collection

Samples were collected during eight campaigns (between July 2003 and March 2005) at each sampling site between 08 and 10 am. Aquatic insects were sampled by means of drift net (mesh size: 250µm) and hand net (mesh size: 250µm). Drifting organisms were collected using a drift net suspended from a hand held rope.

For the hand net, samples were taken by submerging the net and sweeping it through the water column for a distance of ten meters. The net was also bumped against the bottom substrate to dislodge and collect organisms from the sediment. Two replicate samples were collected at each site and at each date. The samples were fixed in 10% formaldehyde. The three samples (1 by drift net and 2 by hand net) at each site and each campaign were pooled for analysis. In the laboratory, specimens were sorted and identified to the lowest possible taxonomic level by means of the keys in [11-15].

At each campaign, each sampling site was characterized by measuring water temperature (TW), pH, conductivity (CND), total dissolved solids (TDS) and dissolved oxygen (DO) with portable sensors. Secchi disk transparency (Trans) measured using a 20-cm-diameter Secchi disk. Canopy and percentage of four substrata (rock, gravel, sand and clay/mud) were once visually assessed according to [16] methodology.

Data analysis

A principal component analysis (PCA) was performed using environmental variables to determine the abiotic typology of sampling stations. This analysis was performed with the matrix consisting of 64 samples (8 stations x 8 campaigns) and 13 environmental variables. With the same matrix, sampling stations were clustered using a hierarchical analysis (Ward linkage method, euclidean distance). Analyses were conducted using the R package [17].

Macroinvertebrate taxa sampled were analyzed by IndVal method to extract indicator taxa of each cluster at each level of classification. IndVal is a method to find indicator taxa and taxa assemblages characterizing groups of samples [18]. For each taxon i in each site group j, we computed the product of A_{ij}, the mean abundance of taxon i in group j compared to the mean abundance of taxon i in all groups in the study, by B_{ij}, the relative frequency of occurrence of taxon i in group j, as follows:

$A_{ij} = Nindividuals_{ij} / Nindividuals_{i}$ (1)

$B_{ij} = Nsites_{ij} / Nsites_{j}$ (2)

$IndVal_{ij} = A_{ij} \times B_{ij} \times 100$ (3)

A given indicator taxon is defined as a taxon mostly present in a single group of sites and present in the majority of the sites belonging to that group. There are thus two components interfering in the computation of the IndVal index: one accounting for the specificity of the taxa, and the second accounting for the fidelity of that taxa to the groups of sites. The indicator value for the taxon i, $IndVal_i$ is the largest value of $IndVal_{ij}$ observed across all groups j of the site typology. It is maximum (100%) when all individuals of a taxon are found in a single group of samples and when the taxon occurs in all samples of that group. The statistical significance of each index is evaluated using a standard permutation test. Sites are randomly reallocated among site groups (clusters) and the indicator values computed for each taxon. For a given taxon, the rank of the observed value in the randomly generated distributions ordered in decreasing order produces a permutational probability. The indicator values can be estimated for any given level of clustering, which constitutes a useful property of the approach. Taxa may have different indicator values according to the clustering level under consideration. Generalist (core) taxa have decreasing values of the indicator index from high level to lower levels of the typology. Specialised (satellite) taxa, on the contrary, display increasing indicator values from higher to lower levels of the typology.

To determine if a taxon was an indicator, we first examined the significance of the test of permutations at statistical level $\alpha = 5\%$ [18]. We also arbitrarily retained a threshold of 25% [19].

RESULTS

Site typology

The results of the PCA showed that 49.25% of the variance in the data was accounted by the two first axes (Figure 2a). From the correlation circle (Figure 2b), one may deduce that the first axis is positively explained by two mesological parameters (velocity and blocks) and negatively by the parameters related to the mineralization (conductivity, TDS, pH) and transparency. The second axis is explained mainly by mesological parameters. It is positively correlated to the canopy, the width of the bed and clay loam and negatively to gravel.

The PCA ordination (Figure 2c) revealed that the axis F1 showed a gradient of disturbance since opposition is observed between relatively disturbed sites (Eh1 and N1) and undisturbed site (S2). In addition, there is a negative gradient of mineralization from upstream to downstream. The axis F2 seemed to correspond to both a river bed substrate and canopy gradient. An opposition is observed between sites hard substrate where the canopy is low and those in soft substrate with a high canopy. Note that the basic criteria for classifying sites are mainly the nature of the waterbed substrate and the mineralization (disturbance) of the water.

The hierarchical cluster analysis indicated that the sites can be classified into four clusters according the mineralization and the nature of waterbed substrate (Figure 3). This classification was done on three levels. The first level contained all sampling sites. The second level separated the sites according to their disturbance degree. Thus, the weakly disturbed sites are distinguished from those that have appeared relatively most disturbed. At the third level, each group is divided into two depending on the nature of the substrate.

Taxonomic composition

A total of 115 taxa of aquatic insects belonging to 51 families and ten orders were recorded (Table 2). The richest orders of insects were Diptera (32 taxa) and Ephemeroptera (24 taxa), followed by Coleoptera (18 taxa). Overall, the macroinvertebrate fauna was predominantly composed of eight taxa (*Labiobaetis gambiae, Polypedilum* sp., *Cricotopus* sp., *Caenis* sp., *Tanytarsus* sp., *Simulium damnosum, Dicercomyzon* sp. and *Nanocladius* sp.), which were present in more than 50 % of the samples.

Taxa indicator of different types of habitat

The method IndVal allowed identifying taxa indicators of habitat types defined from the abiotic typology of sampling sites.

For this analysis, 66 taxa registered in at least 5% of the total number of samples were retained. Among these taxa, only 25 were found indicators of at least one level of the classification (Figure 4). These taxa that an indicator value was higher than 25% and / or for which the permutation test is significant belong to five orders. Ephemeroptera and Diptera are best represented with respectively 10 and 8 taxa. They are followed by Coleoptera (4 taxa), Odonata (2 taxa) and Plecoptera (1 taxon).

The first level of the typology included all the indicator taxa (25). At the second level, 11 taxa were identified as indicators of mineralized sites. These were 6 dipterans (*Polypedilum* sp., *Tanytarsus* sp., *Stictochironomus* sp., *Ablabesmyia* sp., *Ceratopogon* sp. and *Cryptochironomus* sp.), 3 coleopterans (*Limnius* sp., *Elmis* sp. and *Laccophilus* sp.), one ephemeropteran (*Susua* sp.) and one Odonata (*Coenagrion* sp.). As for weakly mineralized sites, they were characterized by eight taxa including 2 Dipterans (*Cricotopus* sp. and *Nanocladius* sp.), 5 Ephemeropterans (*Labiobaetis gambiae*, *Caenis* sp., *Tricorythus* sp., *Dicercomyzon* sp. and *Procloeon sylvicola*) and one Odonata (*Phyllomacromia* sp.).

On the third level, sites relatively mineralized with sandy substrate were characterized by *Susua* sp., *Limnius* sp., *Elmis* sp., *Perla* sp., *Riolus* sp. and *Choroterpes* sp .. Four taxa (*Coenagrion* sp., *Polypedilum* sp., *Stictochironomus* sp. and *Tanytarsus* sp.) appeared as indicators of relatively mineralized sites with clay substrate. Weakly mineralized sites with sandy substrate were associated with four indicator taxa (*Tricorythus* sp., *Ephoron* sp., *Cricotopus* sp. and *Cloeon* sp.). Similary, four taxa (*Caenis* sp. *Dicercomyzon* sp. *Phyllomacromia* sp. and *Compsoneuria njalensis*) were indicators of low mineralized sites on muddy substrate.

Table 2: List of the aquatic insect taxa found at the eight sampling sites. * indicates the presence of taxa.

			Soumié		Eholié		Ehania		Noé	
Orders	**Families**	**Taxa**	**S1**	**S2**	**E1**	**E2**	**Eh1**	**Eh2**	**N1**	**N2**
Collembola	Arthropleona			*				*	*	*
Ephemeroptera	Leptophlebiidae	*Adenophlebiodes* sp.	*	*	*	*	*	*		
		Choroterpes sp.	*	*	*	*	*	*		*
		Euthraulus sp.	*	*			*	*		*
		Hyalophlebia sp.				*				
		Thraulus sp.	*	*		*	*	*		*
	Tricorythidae	*Dicercomyzon* sp.	*	*	*	*	*	*	*	*
		Tricorythus sp.	*	*	*	*	*	*		*
	Machadorythidae	*Machadorythus maculatus*			*	*				
	Ephemerythidae	*Ephemerythus* sp.	*	*			*	*		
	Polymitarcyidae	*Ephoron* sp.						*		*
	Caenidae	*Caenis* sp.	*	*	*	*	*	*	*	*
	Baetidae	*Afrobaetodes* sp.			*		*			*
		Bugilliesia sp.		*						
		Cloeodes dentatus				*				
		Cloeon sp.							*	*
		Cheleocloeon yolandae	*		*			*	*	
		Dabulamanzia babaora	*	*						
		Labiobaetis gambiae	*	*	*	*	*	*	*	*
		Procloeon sylvicola	*	*	*	*	*	*	*	*

			Soumié		Eholié		Ehania		Noé	
Orders	**Families**	**Taxa**	**S1**	**S2**	**E1**	**E2**	**Eh1**	**Eh2**	**N1**	**N2**
		Susua sp.	*	*					*	
	Oligoneuriidae	*Elassoneuria* sp.			*			*		
	Heptageniidae	*Afronurus* sp.	*	*	*	*	*	*	*	*
		Compsoneuria njalensis	*	*	*	*	*	*	*	*
		Notonurus sp.	*	*		*	*	*	*	
Plecoptera	Perlidae	*Neoperla* sp.					*			
Odonata	Calopterygidae	*Phaon iridipennis*					*			
	Coenagrionidae	*Coenagrion* sp.	*	*	*		*	*	*	
		Pseudogrion sp.			*					
	Gomphidae	*Lestinogomphus angustus*		*		*		*	*	
		Microgomphus sp.		*	*					
		Paragomphus sp.	*				*	*	*	
		Phyllogomphus aethiops			*	*	*	*	*	
	Cordulegasteridae	*Cordulegaster* sp.	*							
	Libellulidae	*Libellula* sp.			*	*				
		Olpogastra sp.					*	*		
		Zygonyx sp.		*						
		Palpopleura sp.					*			
	Macromiidae	*Macromia* sp.	*	*	*		*	*	*	*
		Phyllomacromia sp.	*	*	*	*	*		*	
	Chlorocyphidae	*Chlorocypha* sp.					*			
Heteroptera	Pleidae	*Plea* sp.		*		*	*		*	
	Notonectidae	*Anisops* sp.		*	*			*	*	
	Corixidae	*Micronecta scutellaris*	*		*					*
	Hydrometridae	*Hydrometra* sp.					*		*	
	Veliidae	*Microvelia* sp.		*			*	*	*	
Heteroptera	Veliidae	*Rhagovelia reitteri*	*	*	*		*	*		
	Gerridae	*Eurymetra* sp.			*	*	*	*	*	
		Gerris sp.	*							
	Belostomatidae	*Diplonychus* sp.			*					
		Limnogeton fieberi					*			
Lepidoptera	Crambidae					*	*	*	*	*
Hymenoptera			*	*			*	*		
Coleoptera	Gyrinidae	*Orectogyrus* sp.	*	*				*		
	Dytiscidae	*Copelatus* sp.							*	
		Dytiscus sp.	*		*		*		*	
		Laccophilus sp.	*	*	*		*	*	*	
	Hydrophilidae	*Enochrus* sp.						*		*
		Hydrobius sp.		*						*
	Elmidae	*Potamophilus* sp.					*			
		Potamodytes sp.		*			*		*	
		Elmis sp.	*	*	*	*	*	*	*	*
		Esolus sp.		*	*	*	*	*	*	*
		Limnius sp.	*	*	*	*	*	*	*	*
		Normandia sp.	*	*	*				*	
		Riolus sp.	*	*	*	*	*	*	*	*
		Dupophilus sp.		*	*	*	*	*	*	
		Oulimnius sp.	*		*	*	*			
		Macronychus sp.	*				*	*		
	Helodidae		*							
	Hydroscaphidae	*Hydroscapha* sp.		*						
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	*	*				*	*	
		Polymorphanisus sp.								*
	Polycentropodidae	*Neureclipsis* sp,				*				

			Soumié		Eholié		Ehania		Noé	
Orders	**Families**	**Taxa**	**S1**	**S2**	**E1**	**E2**	**Eh1**	**Eh2**	**N1**	**N2**
	Ecnomidae	*Ecnomus* sp.					*	*		
	Hydroptilidae	*Afritrichia* sp.	*				*	*	*	
		Hydroptila sp.			*		*		*	
		Orthotrichia sp.		*	*	*			*	
	Leptoceridae	*Ceraclea* sp.		*	*	*	*	*		
		Leptocerus sp.	*				*	*		
		Oecetis sp.	*	*	*			*	*	
		Triaenodes sp.		*		*				*
		Parasetodes sp.	*	*	*					
Diptera	Psychodidae									*
	Ptychopteridae	*Ptychopteria* sp.								*
	Chaoboridae	*Chaoborus* sp.								*
	Culicidae	*Aedes* sp.					*			
		Anopheles sp.	*	*	*		*	*	*	
		Culex sp.			*					
		Culicinae	*							
	Simuliidae	*Simulium damnosum*	*	*		*	*	*	*	*
	Ceratopogonidae	*Ceratopogon* sp.	*	*	*	*	*	*	*	
		Dasyheleinae							*	
		Forcipomyinae						*		
	Chironomidae	*Ablabesmyia* sp.	*	*	*	*	*	*	*	*
		Chironomus sp.	*	*	*	*	*	*	*	*
		Clinotanypus claripennis		*	*	*	*	*	*	*
Diptera	Chironomidae	*Cricotopus* sp.	*	*	*	*	*	*	*	*
		Cryptochironomus sp.	*	*	*	*	*	*	*	*
		Lauterborniella sp.						*		
		Nanocladius sp.	*	*	*	*	*	*	*	*
		Nilodorum sp.			*	*	*	*	*	*
		Orthocladiinae	*		*				*	
		Polypedilum sp.	*	*	*	*	*	*	*	*
		Procladius sp.			*					
		Stenochironomus sp.	*		*	*	*			
		Stictochironomus sp.	*	*	*	*	*	*	*	*
		Tanypus sp.			*		*		*	*
		Tanytarsus sp.	*	*	*	*	*	*	*	*
	Stratiomyidae								*	
	Empididae	Hemerodromiinae							*	*
	Athericidae	*Atherix* sp.	*			*	*	*		*
	Anthomyidae			*						
	Tabanidae	*Tabanus* sp.			*		*	*		*
	Tipulidae							*	*	

DISCUSSION

The factorial analysis showed that the parameters related to the mineralization (conductivity, TDS, pH), transparency and mesological parameters such as substrate type, current velocity, the width of the wet bed and canopy appeared the most discriminating in classifying sampling sites. Some sites seemed most mineralized. These are Eh1 and N1 stations. This could be explained by their proximity to homes. Indeed, the combined effect of inputs arising from the strong agricultural activity in the area and domestic discharges could contribute to the mineralization of these portions of rivers.

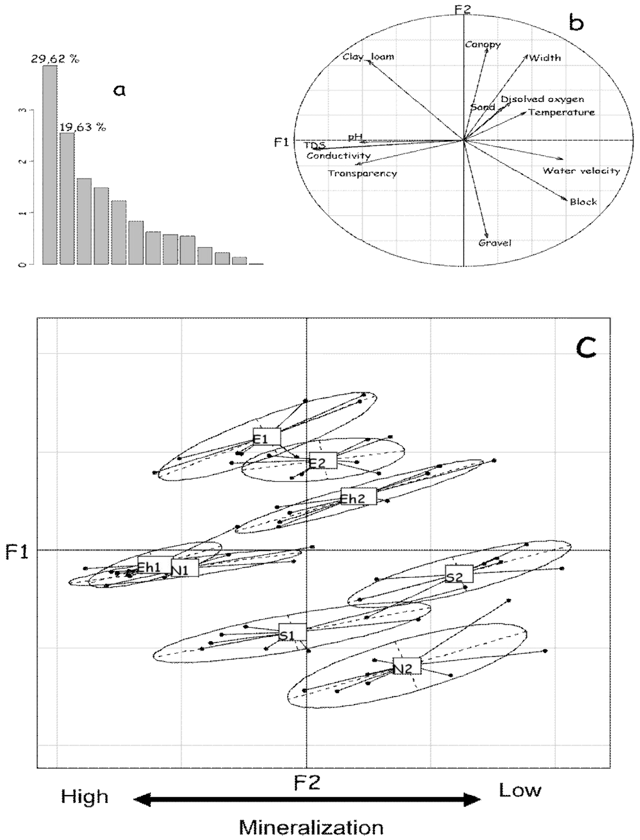

Figure 2: Principal Component Analysis (PCA) on environmental variables (8 sites x 13 variables x 8 campaigns): a) Histogram of eigenvalues. b) Correlation circle on the factorial plane F1 x F2. c) Factorial map of the sampling sites the factorial plane F1 x F2. 1 and 2 represent upstream and downstream sites on Soumié (S), Eholié (E), Ehania (Eh) and Noé (N) rivers.

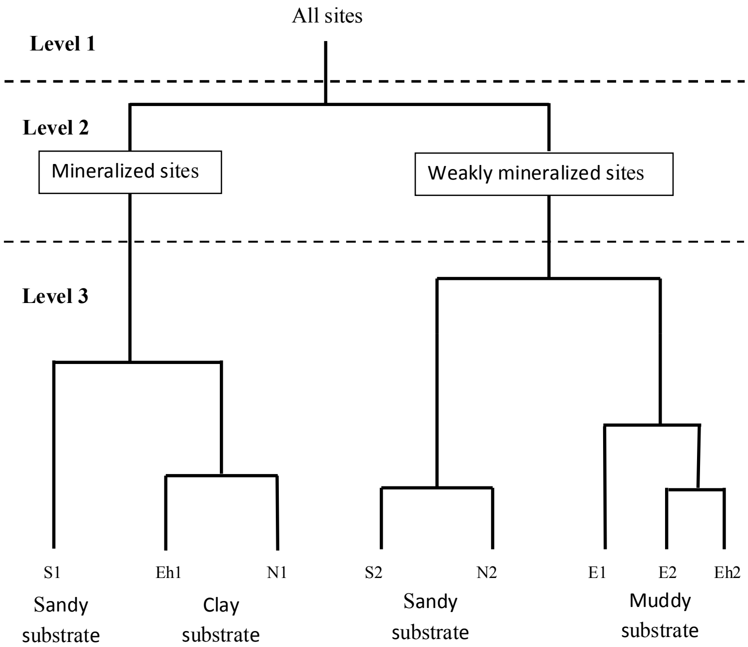

Figure 3: Sampling site typology run by the hierarchical cluster analysis on environmental variable data. 1 and 2 represent upstream and downstream sites on Soumié (S) Eholié (E), Ehania (Eh) and Noé (N) rivers.

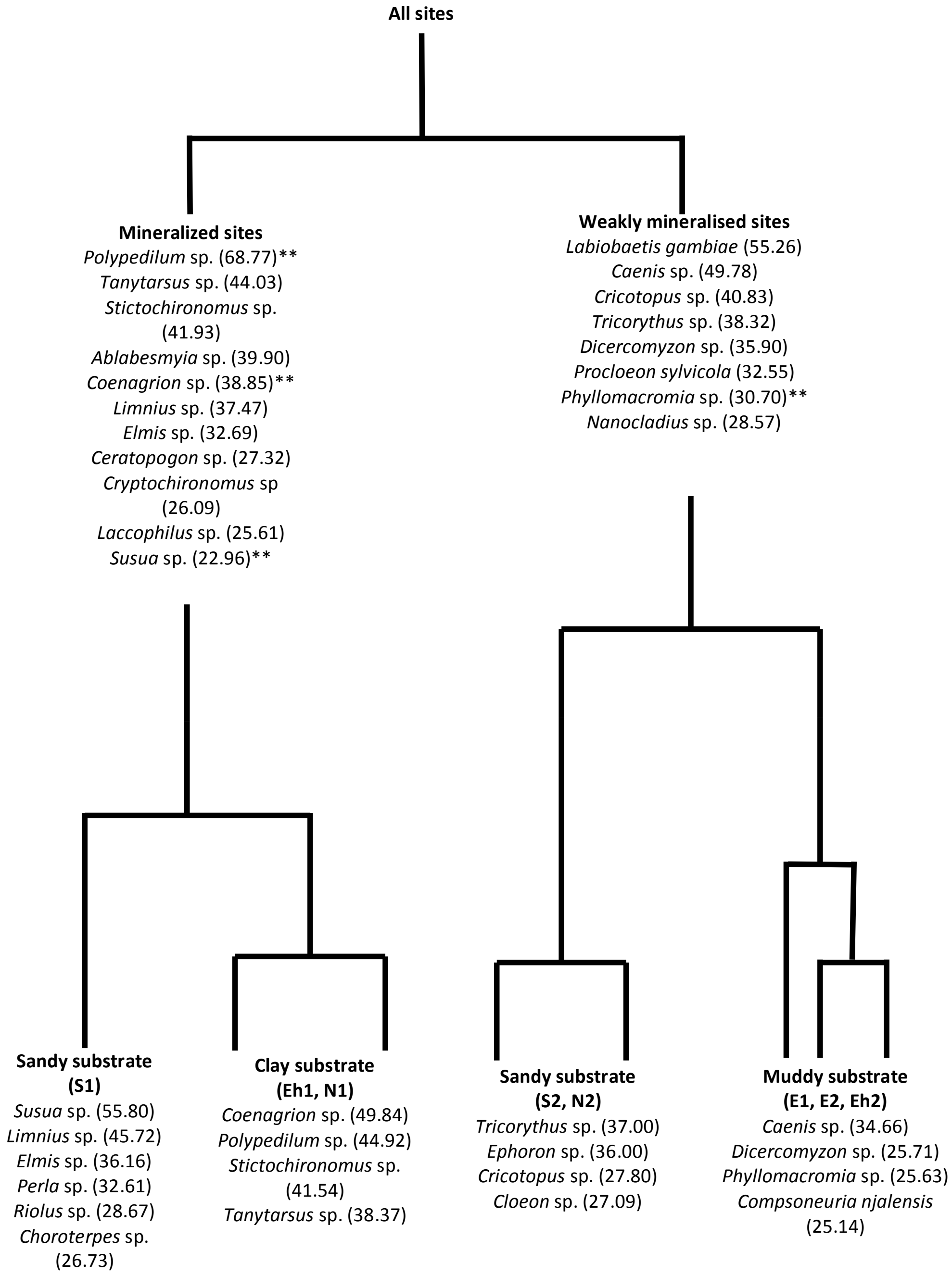

Figure 4: Sampling sites typology and indicator taxa associated with the indicator values in brackets. ** = significant test of permutations. 1 and 2 represent upstream and downstream sites on Soumié (S) Eholié (E), Ehania (Eh) and Noé (N) rivers

Overall, the mineralization of the waters of different rivers followed an upstream downstream negative gradient. Rivers drained silty substrates in the headwaters where agricultural activities are intense, which favors the enrichment of water bodies in various salts in these areas as it was shown by [20] and [21] in streams respectively in China and Nigeria**.** The low mineralization observed downstream is due to the phenomenon of dilution [22].

Among the 115 taxa recorded in this study, most (72) are reported for the first time from this area. Previous studies [23, 24] found 17 taxa which were not recorded in the present study. Several reasons can account for the discrepancies between studies: the sampling methods used, types of habitats sampled, sampling periods and the number of rivers. Indeed, [23] described only the benthic macrofauna on the Bia River, whereas the study of [24] was devoted to nycthemeral variation of drifting insects on the same river. The high number of new records resulting from this study indicates that the list of insect taxa is probably still not complete. Taxonomic richness differs between sites. This disparity is related to local environmental conditions such as granulometry of substrate or the water bed stability. These factors influence the diversity of aquatic macroinvertebrates [25, 26].

The IndVal method [18] allowed classifying aquatic insects according to the degree of site disturbance and the nature of the substrate. Of all the collected insects, dipterans represented the most of characteristic taxa of the most mineralized sites. However, the indicator taxa of weakly mineralized sites are mainly ephemeropterans. Among all aquatic insect orders registered in this study, Diptera are known as the most resistant to dsiturbance while Ephemeroptera are polluo-sensitive [27, 28]. This could explain the high number of Diptera and Ephemeroptera respectively among indicator taxa of the most mineralized and weakly mineralized sites.

Some taxa were found as indicators on the second level and were not included in the indicator taxa in the third level of the classification. They would be generalist with respect to the substrate nature. So they have no preference between the different types of substrate. These are *Laccophilus* sp., *Ablabesmyia* sp., *Ceratopogon* sp. and *Cryptochironomus* sp. for the most mineralized sites. For weakly mineralized sites, these taxa are *Labiobaetis gambiae*, *Procloeon sylvicola* and *Nanocladius* sp..

In addition, some taxa were indicators at the third level of site typology but they were not indicators at the second level. They would be specialists for substrate types. Such is the case of *Riolus* sp. *Perla* sp. and *Choroterpes* sp. which were characteristic to the relatively mineralized sites with mainly sandy substrate. *Cloeon* sp. and *Ephoron* sp. were specialists of weakly mineralized sites with substrate dominated by sand, while *Compsoneuria njalensis* was characteristic of weakly mineralized habitats whose bottom is muddy.

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REFERENCES

1. Nanami, A., Saitoa, H., Akitab, T., Motomatsuc, K. & Kuwahara, H. (2005). Spatial distribution and assemblage structure of macrobenthic invertebrates in a brackish lake in relation to environmental variables. Estuar. Coast. Shelf S., 63:167-176
2. Minshall, G.W. & Robinson, C.T. (1998). Macroinvertebrate community structure in relation to measures of lotic heterogeneity. Arch. Hydrobiol., 141:129-151.
3. Ramirez, A., Paaby, P., Pringle, C.M. & Agüero, G. (1998). Effect of habitat type on benthic macro invertebrates in two lowland tropical streams, Costa Rica. Rev. Biol. Trop., 46:201-2 I3.
4. Sankaré, Y. (1991). Etude comparative de la macrofaune associée aux racines de *Pistia stratiotes* L (Araceae) du lac de barrage d'Ayamé II et du fleuve Comoé (Côte d'Ivoire). J. Ivoir. Oceanol. Limnol., 1:131-138.
5. Lévêque, C., Hougard, J.M., Resh, V., Statzner, B. & Yaméogo, L. (2003). Freshwater ecology and biodiversity in the tropics: what did we learn from 30 years of onchocerciasis control and the associated biomonitoring of West African rivers? Hydrobiologia, 500:23-49.
6. Edia, O.E., Brosse, S., Ouattara, A., Gourène, G., Winterton, P., Lek-Ang, S. (2007). Aquatic insect assemblage patterns in four West-African coastal rivers. J. Biol. Sci., 7:1130-1138.
7. Edia, O.E., Gevrey, M., Ouattara, A., Brosse, S., Gourène, G., Lek, S. (2010). Patterning and predicting aquatic insect richness in four West-African coastal rivers using artificial neural networks. Knowl. Manag. Aquat. Ec., 398, 06.
8. Kouamé, M.K., Diétoa, M.Y., Da Costa, S.K., Edia, O.E., Ouattara, A. & Gourène, G. (2010). Aquatic macroinvertebrate assemblages associated with root masses of water hyacinths, *Eichhornia crassipes* (Mart.) Solms-Laubach, 1883 (Commelinales: Pontederiaceae) in Taabo Lake, Ivory Coast. J. Nat. Hist., 44(5-8):257-278.
9. Kouamé, M.K., Diétoa, M.Y., Edia, O.E., Da Costa, S.K., Ouattara, A. & Gourène, G. (2011). Macroinvertebrate communities associated with macrophyte habitats in a tropical man-made lake (Lake Taabo, Côte d'Ivoire). Knowl. Manag. Aquat. Ec., 400, 03.
10. Smogor, R.A. & Angermeier, P.L. (1999). Effects of drainage basin and anthropogenic disturbance on relations between stream size and IBI metrics in Virginia. (Ed. Simon T.P.) Assessment Approaches for Estimating Biological Integrity Using Fish Assemblages, Lewis Press, Boca Raton, p.249–272.
11. Déjoux, C., Elouard, J.M., Forge, P. & Maslin, J.L. (1981). Catalogue iconographique des insectes aquatiques de Côte d'Ivoire. Report ORSTOM, Bouaké, Côte d'Ivoire, pp.172.
12. Day, J.A., Harrison, A.D. & de Moor, I.J. (2002). Guides to the Freshwater Invertebrates of Southern Africa, Volume 9: Diptera, WRC report N° TT 201/02, South Africa, pp.200.
13. de Moor, I.J., Day, J.A. & de Moor, F.C. (2003a). Guides to the Freshwater Invertebrates of Southern Africa, Volume 7: Insecta I: Ephemeroptera, Odonata and Plecoptera, WRC report N° TT 207/03, South Africa, pp.288.
14. de Moor, I.J., Day, J.A. & de Moor, F.C. (2003b). Guides to the Freshwater Invertebrates of Southern Africa. Volume 8: Insecta II: Hemiptera, Megaloptera, Neuroptera, Trichoptera and Lepidoptera. WRC report N° TT 214/03, South Africa, pp.209.
15. Stals, R. & de Moor, I.J. (2007). Guides to the Freshwater Invertebrates of Southern Africa, Volume 10: Coleoptera, WRC report N° TT 320/07, South Africa, pp.263.

16. Gordon, N.D., McMahon, T.A. & Finlayson, B.L. (1994). Stream Hydrology, an Introduction for Ecologists, John Wiley and Sons, New York, pp.526.
17. Ihaka, R. & Gentleman, R. (1996). R: a language for data analysis and graphics. J. Comput. Graph. Statis., 5:299-314.
18. Dufrêne, M. & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr., 67:345-366.
19. Nahmani, J. & Rossi, J.-P. (2003). Soil macroinvertebrates as indicators of pollution by heavy metals. C. R. Biol., 326:295-303.
20. Neumann, M. & Dudgeon, D., (2002). The impact of agricultural runoff on stream benthos in Hong Kong, China. Water Res., 36: 3103-3109.
21. Arimoro, F. O., & Ikomi, R. B. (2008). Response of macroinvertebrates to abattoir wastes and other anthropogenic activities in a municipal stream in the Niger Delta, Nigeria. Environmentalist, 28:85–98.
22. Bengen, D., Lim, P. & Beland, A. (1992). Qualité des eaux de trois bras morts de la Garonne : variabilité spatio-temporelle. Rev. Sci. Eau, 5:131-156.
23. Diomandé, D. (2001). Macrofaune benthique et stratégies alimentaires de *Synodontis bastiani* et *S. schall* en milieu fluvio-lacustre (Bassins Bia et Agnébi, Côte d'Ivoire). Thèse de Doctorat, Université d'Abobo-Adjamé, Abidjan, Côte d'Ivoire, pp.260.
24. Diétoa, Y. M. (2002). Entomofaune et stratégies alimentaires des poissons du genre *Brycinus* (Characidae) en milieux fluviatiles et lacustre (Bassins Bia et Agnéby; Côte d'Ivoire). Thèse de Doctorat, Université d'Abobo-Adjamé, Abidjan, Côte d'Ivoire, pp.261.
25. Townsend, C. R., Scarsbook, M. R. & Doledec, S. (1997). The intermediate disturbance hypothesis, refugia and biodiversity in streams. Limnol. Oceanogr., 20:938-949.
26. Matthaei, C.D., Peacock, K.A. & Townsend, C.R. (1999). Patchy surface stone movement during disturbance in a New Zealand stream and its potential significance for fauna. Limnol. Oceanogr., 44:1091-1102.
27. Mathuriau, C. (2002). Les macroinvertébrés des cours d'eau andins du Sud-est de la Colombie : écologie et bioindication. Thèse de Doctorat, Université Paul Sabatier, Toulouse, France, pp.309.
28. Arimoro, F. O., Ikomi, R. B. & Iwegbue, C. M. A. (2007). Water quality changes in relation to Diptera community patterns and diversity measured at an organic effluent impacted stream in the Niger Delta, Nigeria. Ecol. Indic., 7:541-552.

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