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Aquatic Insect Assemblage Patterns in Four West-African Coastal Rivers

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Abstract: We analysed aquatic insect richness and assemblage patterns in four coastal rivers 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. Overall, 124 taxa belonging to 53 families and ten orders were recorded. The richest taxon diversity was observed for Diptera and Ephemeroptera. The settlement of aquatic insects presented strong similarity between sites. In addition, beta diversity assessment showed that the dispersal of aquatic insects was random (Mantel tests, $p>0.05$) i.e., their taxonomic composition was homogeneous over the area covered by the four rivers, suggesting that they belong to the same ecoregion. So, as these rivers are subject to little anthropogenic disturbance compared to other streams in the same region, we suggest using them as reference systems with a view to initiating conservation and/or biomonitoring programs.

Key words: Aquatic insects, community structure, alpha diversity, beta diversity, coastal rivers, West Africa

INTRODUCTION

Aquatic ecosystems are under increasing pressure from various kinds of disturbances (Tachet *et al.*, 2003). This situation threatens both aquatic living resources and human populations (Ramade, 2002). Water quality monitoring systems were set up to tackle this threat and to preserve biodiversity and many use macroinvertebrates as indicators (Armitage *et al.*, 1983; Rosenberg and Resh, 1993; Wright *et al.*, 1995; Williams and Smith, 1996; Clarke *et al.*, 2002). However, such systems require good knowledge of the taxonomic assemblages present. In many tropical areas, there is a crucial lack of basic information on macrioinvertebrate assemblages. This fact impedes their use in conservation and biomonitoring programs.

In West Africa, the diversity of aquatic invertebrates is little known (Yaméogo *et al.*, 2004). In Ivory Coast, only a few studies have been devoted to macroinvertebrate fauna to date (Dejoux *et al.*, 1981; Sankaré, 1991; Diomandé, 2001; Diétoa, 2002). Among them, two were conducted in southeast Ivory Coast. They only described the macroinvertebrate fauna of the Bia River (Diomandé, 2001; Diétoa, 2002), so there is no information on other rivers in this region. This study, focussed on four small coastal rivers which play an important role for human populations in southeast Ivory Coast. These rivers, like other coastal rivers of Ivory Coast are used for domestic activities (drinking, cooking, bathing...), agriculture (irrigation, cattle drinking) and fisheries. However, compared to other Ivory Coast rivers (e.g., San Pedro, Bia and Agnébi rivers), these aquatic systems face few anthropogenic impacts (no dams or large cities). Therefore, it is promising to characterize these rivers communities for further use as reference in biomonitoring and conservation programs.

This study was focussed on aquatic insect assemblages in eight sites dispersed over four rivers, Soumié, Eholié, Ehania and Noé, in the southeast part of Ivory Coast. Present aim was firstly to describe the aquatic insect composition of the rivers and secondly to analyse the richness patterns between sites and between river basins.

MATERIALS AND METHODS

Study area: The study was undertaken in four coastal rivers located in the South-East of Ivory Coast (Fig. 1): Soumié, Eholié, Noé and Ehania rivers. Soumié River is a tributary of the Bia River. Its drainage area covers 395 km^2.

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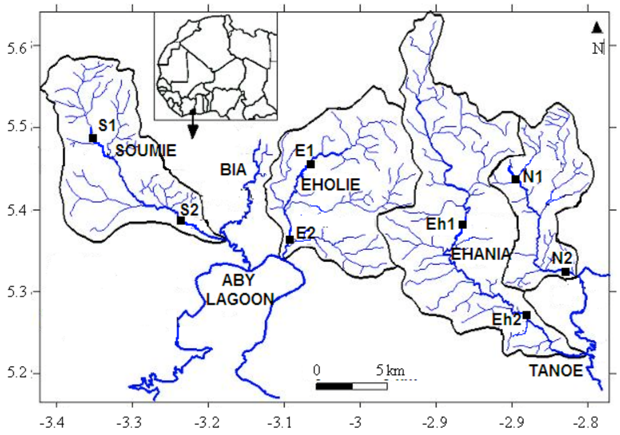

Fig. 1: Location of the study area showing the four rivers studied. S1 and S2: upstream and downstream on Soumié; E1 and E2: upstream and downstream on Eholié; Eh1 and Eh2: upstream and downstream on Ehania; N1 and N2: upstream and downstream on Noé. Dot marks indicate the sampling points on the four rivers

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

	Soumié river		Eholié river		Ehania river		Noé river	
Characters	Site S1	Site S2	Site E1	Site E2	Site Eh1	Site Eh2	Site N1	Site N2
Geographical positions	05° 29’ N	05° 24’ N	05° 28’ N	05° 23’ N	05° 24’ N	05° 17’ N	05° 28’ N	05° 18’ N
	03° 22’ W	03° 17’ W	03° 08’ W	03° 08’ W	02° 55’ W	02° 50’ W	02° 51’ W	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 sec^{-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 habitat building along the banks, High: Continuous habitat

It is 41 km in length with a mean annual flow of 11.76 m^3 sec^{-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 m^3 sec^{-1} . The rivers Noé and Ehania are both tributaries of Tanoé river. Their catchments cover respectively 238 and 585 km^2. 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 m^3 sec^{-1}. The River Noé which is a straight 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 m^3 sec^{-1} .

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

Aquatic insects sampling: Aquatic macroinvertebrates were collected at each site on eight occasions (i.e., four during the rainy season and four during the dry season) between July 2003 and March 2005. They were sampled by means of drift net (mesh size: 250 µm) and a hand net (mesh size: 250 µm). Drifting organisms were collected using the drift net suspended from a hand held rope. The openings of the nets were orientated against river flow for 15 min.

A hand net was also used to obtain semi-quantitative samples. A sample was collected by submerging the net and sweeping it through the water column for a distance of 10 m. The net was also bumped against the bottom substrate to dislodge and collect organisms from the sediment. All material collected was placed in a sieve bucket. Pieces of vegetation were washed and discarded. Two replicate samples were collected at each site and at each date. The samples were preserved in 10% formaldehyde. The three samples at each site and each occasion were pooled for analysis.

In the laboratory, specimens were sorted and identified to the lowest possible taxonomic with help of the keys in Déjoux *et al.* (1981), Diomandé *et al.* (2000), De Moor *et al.* (2003) and Tachet *et al.* (2003) and consulting specialists.

All macroinvertebrates were counted, but to avoid biases due to both patchiness in invertebrate spatial distribution and temporal dynamics of abundance (Williams and Feltmate, 1992), only presence/absence was considered in the following analyses.

Data analysis: Alpha diversity was assessed using taxon richness (S). Taxon richness at each site is the total number of taxa collected through the sampling period. Analyses were performed with a correlation matrix between the eight sites and 74 taxa. Rare taxa (taxa which appeared in less than 5% of the samples) were removed from the analyses.

Because of the low seasonal variation of taxonomic richness, outlined by the preliminary Mann-Whitney tests, Factorial Component Analysis (FCA) was carried out with the matrix of total taxa presence/absence per site. This analysis was run to determine spatial distribution of aquatic insects. With the same matrix, the taxonomic similarity between sites was then investigated using a hierarchical analysis (Ward linkage method, Binary distance). Significant differences in taxa richness between the clusters were determined using Kruskal-Wallis and Mann-Whitney tests. Analyses were conducted using the R package (Ihaka and Gentleman, 1996).

The beta diversity index was applied to quantify turnover in taxon composition along longitudinal (sites belonging to the same river) and transversal (sites belonging to different rivers) gradients (Wilson and Shmida, 1984; Blackburn and Gaston, 1996). Because the number of sites differed between gradients (i.e., n = 2 for longitudinal gradient and n = 4 for transversal gradient), we used Whittaker's index (β_w) (Whittaker, 1972), calculated as:

$$\beta_w = (S_R/\alpha_{mean})-1$$

For the longitudinal gradient, beta diversity was evaluated between upstream and downstream sites of each river, with S_R = total richness in each river and α_{mean} = mean richness of sites within each river. For the transversal gradient, two comparisons were made: between the upstream sites of the four rivers and between the downstream sites of the four rivers, with S_R = total richness in each zone and α_{mean} = mean richness of sites within each zone. Finally, beta diversity was also evaluated between all sites with S_R = total richness in a pair of sites and α_{mean} = mean richness in the two sites. That allowed the calculation of the matrix of β-diversity indices between each pair of sites.

The Mantel test (Fortin and Gurevitch, 1993) was then employed to assess the null hypothesis that β-diversity patterns are random and, therefore, not related to the fact that sites belong to the same river. The Mantel test involves the use of a correlation matrix between the matrix of pairwise β-diversity indices and a model matrix, with value 0 for pairs of sampling sites in the same river and value 1 in different rivers. Significance was assessed by comparing the actual value with a set of values generated using 1000 permutations of the β-diversity matrix.

RESULTS

Taxonomic composition and spatial distribution: A total of 124 taxa of aquatic insects belonging to 53 families and 10 orders were recorded (Table 2). The richest orders of

Table 2: List of the aquatic insect taxa found at the eight sampling sites. As a comparison, species lists established by Dimoandé (2001) and Dietoa (2002) in the Bia River are also given. See Fig. 1 for sites acronyms

						This study							
					Diétoa	Soumié		Eholié		Ehania		Noé	
Order	Family	Taxon	Acronym	Diomandé	Bia river	S1	S2	E1	E2	Eh1	Eh2	N1	N2
Collembola		Arthropleona	Arthr		x		x				x	x	x
Ephemeroptera	Leptophlebiidae	*Adenophlebiodes* sp.	Adeno		x	x	x	x	x	x	x		
		Choroterpes sp.	Choro			x	x	x	x	x	x		x
		Euthraulus sp.	Euthr			x	x			x	x		x
		Fulletomimus sp.		x	x								
		Hyalophlebia sp.	Hyalo						x				
		Thraulus sp.	Thrau	x	x	x	x		x	x	x		x
	Tricorythidae	*Dicercomyzon* sp.	Dicer	x	x	x	x	x	x	x	x	x	x
		Tricorythus sp.	Trico		x	x	x	x	x	x	x		x
	Machadorythidae	*Machadorythus maculatus*	Macha	x				x	x				
	Ephemerythidae	*Ephemerythus* sp.	Ephe			x	x			x	x		
	Polymitarcyidae	*Ephoron* sp.	Ephor								x		x
		Povilla sp.		x	x								
	Caenidae	*Caenis* sp.	Caeni		x	x	x	x	x	x	x	x	x
	Ephemerellidae	*Ephemerella* sp.	Ephem						x	x			
		Torleya sp.	Torle			x			x				
	Baetidae	*Afrobaetodes* sp.	Afrob		x			x		x			x
		Bugilliesia sp.	Bugil				x						

Table 2: Continued

						This study							
					Diétoa	Soumié		Eholié		Ehania		Noé	
Order	Family	Taxon	Acronym	Diomandé	Bia river	S1	S2	E1	E2	Eh1	Eh2	N1	N2
		Centroptilum sp.		x	x								
		Cloeodes dentatus	Clode						x				
		Cloeon sp.	Cleon	x	x							x	x
		Cheleocloeon yolandae	Cheyo			x		x			x	x	
		Compsoneuria njalensis	Conja			x	x	x	x	x	x	x	x
		Dabulamanzia babaora	Dabab			x	x						
		Labiobaetis gambiae	Labga			x	x	x	x	x	x	x	x
		Procloeon sylvicola	Prosy			x	x	x	x	x	x	x	x
		Susua sp.	Susua			x	x					x	
	Oligoneuriidae	*Elassoneuria* sp.	Elass		x			x			x		
		Oligoneuriopsis sp.	Oligo								x		
	Heptageniidae	*Afronurus* sp.	Afron		x		x	x	x	x	x	x	x
		Ecdyonurus sp.	Ecdyo			x	x	x	x	x	x	x	
		Epeorus sp.	Epeor							x	x	x	
		Heptagenia sp.	Hepta			x	x	x	x	x	x		x
		Notonurus sp.	Noton		x	x	x		x	x	x	x	
	Neoephemeridae	*Neoephemera* sp.	Neoep						x				
	Euthyplociidae	*Exeuthyplocia* sp.			x								
Plecoptera	Perlidae	*Neoperla* sp.	Neope	x	x					x			
		Perla sp.	Perla			x	x	x			x		
Odonata	Calopterygidae	*Phaon iridipennis*	Phaon							x			
	Coenagrionidae	*Coenagrion* sp.	Coena			x	x	x		x	x	x	
		Pseudogrion sp.	Pseudo					x					
	Gomphidae	*Ictinogomphus* sp.		x									
		Lestinogomphus angustus	Lesti	x			x		x		x	x	
		Microgomphus sp.	Micro				x	x					
		Paragomphus sp.	Parag	x		x				x	x	x	
		Phyllogomphus aethiops	Phyllo	x				x	x	x	x	x	
	Cordulegasteridae	*Cordulegaster* sp.	Cordu			x							
	Libellulidae	*Libella* sp.	Libell									x	
		Libellula sp.	Libel					x	x				
		Olpogastra sp.	Olpog							x	x		
		Zygonyx sp.	Zygon				x						
		Palpopleura sp.	Palpo							x			
	Macromiidae	*Macromia* sp.	Macro			x	x	x		x	x	x	x
		Phyllomacromia sp.	Phyll	x		x	x	x	x	x		x	
	Chlorocyphidae	*Chlorocypha* sp.	Chlor							x			
Heteroptera	Pleidae	*Plea* sp.	Plea		x		x		x	x		x	
	Notonectidae	*Anisops* sp.	Aniso				x	x			x	x	
	Corixidae	*Micronecta scutellaris*	Micron	x		x		x					x
		Stenocorixa sp.			x								
	Hydrometridae	*Hydrometra* sp.	Hydrom							x		x	
	Veliidae	*Microvelia* sp.	Microv	x			x			x	x	x	
		Rhagovelia reitteri	Rhago			x	x	x		x	x		
	Gerridae	*Eurymetra* sp.	Eurym		x			x	x	x	x	x	
		Gerris sp.	Gerri			x							
	Belostomidae	*Diplonychus* sp.	Diplo		x			x					
		Limnogeton fieberi	Limno							x			
	Nepidae	*Laccotrephes* sp.		x									
	Aphelocheiridae	*Aphelocheirus* sp.		x									
Lepidoptera	Crambidae		Cramb						x	x	x	x	x
Hymenoptera			Hymne			x	x			x	x		
Coleoptera	Gyrinidae	*Orectogyrus* sp.	Orect		x	x	x				x		
	Dytiscidae	*Copelatus* sp.	Copel									x	
		Dytiscus sp.	Dysti			x		x		x		x	
		Hydaticus sp.		x									
		Laccophilus sp.	Lacco	x	x	x	x	x		x	x	x	
		Neptosternus sp.		x									
	Hydrophilidae	*Amphiops* sp.			x								
		Enochrus sp.	Enoch	x	x						x		x
		Hydrobius sp.	Hydrob				x						x
		Hydrophilus sp.			x								

Table 2: Continued

						This study							
					Diétoa	Soumié		Eholié		Ehania		Noé	
Order	Family	Taxon	Acronym	Diomandé	Bia river	S1	S2	E1	E2	Eh1	Eh2	N1	N2
	Elmidae	*Dupophilus* sp.	Dupop				x	x	x	x	x	x	
		Elmis sp.	Elmis			x	x	x	x	x	x	x	x
		Esolus sp.	Esolu				x	x	x	x	x	x	x
		Limnius sp.	Limni			x	x	x	x	x	x	x	x
		Macronychus sp.	Macro			x				x	x		
		Microdinides sp.		x									
		Normandia sp.	Norma			x	x	x				x	
		Oulimnius sp.	Oulim			x		x	x	x			
		Potamodytes sp.	Pota		x		x			x		x	
		Potamophilus sp.	Potam							x			
		Pseudancyronyx sp.		x									
		Pseudomacronychus sp.		x									
		Riolus sp.	Riolu			x	x	x	x	x	x	x	x
	Helodidae		Helod			x							
	Hydroscaphidae	*Hydricapha* sp.	Hydri				x						
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	Cheum		x	x	x				x	x	
		Polymorphanisus sp.	Polym		x								x
	Polycentropodidae	*Neureclipsis* sp,	Neure						x				
	Ecnomidae	*Ecnomus* sp.	Ecnom		x					x	x		
	Hydroptilidae	*Afritrichia* sp.	Afrit			x				x	x	x	
		Hydroptila sp.	Hydrop		x			x		x		x	
		Orthotrichia sp.	Ortho				x	x	x			x	
	Leptoceridae	*Ceraclea* sp.	Cerac				x	x	x	x	x		
		Leptocerus sp.	Lepto			x				x	x		
		Oecetis sp.	Oecet		x	x	x	x			x	x	
		Triaenodes sp.	Triae				x		x				x
		Lytocerus sp.	Lytoc									x	
		Parasetodes sp.	Paras		x	x	x	x					
Diptera	Psychodidae		Psych		x								x
	Ptychopteridae	*Ptychopteria* sp.	Ptych										x
	Chaoboridae	*Chaoborus* sp.	Chaob	x	x								x
	Culicidae	*Aedes* sp.	Aedes		x					x			
		Anopheles sp.	Anoph		x	x	x	x		x	x	x	
		Culex sp.	Culex		x			x					
	Simuliidae	*Simulium damnosum*	Simul			x	x		x	x	x	x	x
	Ceratopogonidae	*Ceratopogon* sp.	Cerat		x	x	x	x	x	x	x	x	
		Bezzia sp.		x									
		Dasyheleinae	Dasyh									x	
		Forcipomyinae	Forci								x		
	Chironomidae	*Ablabesmyia* sp.	Ablab	x	x	x	x	x	x	x	x	x	x
		Chironomus sp.	Chiro	x	x	x	x	x	x	x	x	x	x
		Clinotanypus claripennis	Clinot		x		x	x	x	x	x	x	x
		Cricotopus sp.	Crico		x	x	x	x	x	x	x	x	x
		Cryptochironomus sp.	Crypt	x	x	x	x	x	x	x	x	x	x
		Lauterborniella sp.	Laute								x		
		Nanocladius sp.	Nanoc		x	x	x	x	x	x	x	x	x
		Nilodorum sp.	Nilod	x	x			x	x	x	x	x	x
		Orthocladiinae	Orthoc			x		x				x	
		Polypedilum sp.	Polyp	x	x	x	x	x	x	x	x	x	x
		Procladius sp.	Procla	x	x			x					
		Stenochironomus sp.	Steno	x		x		x	x	x			
		Stictochironomus sp.	Stict	x	x	x	x	x	x	x	x	x	x
		Tanypus sp.	Tanyp	x	x			x		x		x	x
		Tanytarsus sp.	Tanyt	x	x	x	x	x	x	x	x	x	x
	Stratiomyidae		Strat									x	
	Empididae	Hemerodromiinae	Hemer									x	x
	Athericidae	*Atherix* sp.	Ather	x		x			x	x	x		x
	Anthomyidae		Antho				x						
	Tabanidae	*Tabanus* sp.	Taban					x		x	x		x
	Cecidomyidae	*Cecidomyia* sp.		x	x								
	Tipulidae		Tipul								x	x	
	Dixidae	*Dixia* sp.			x								

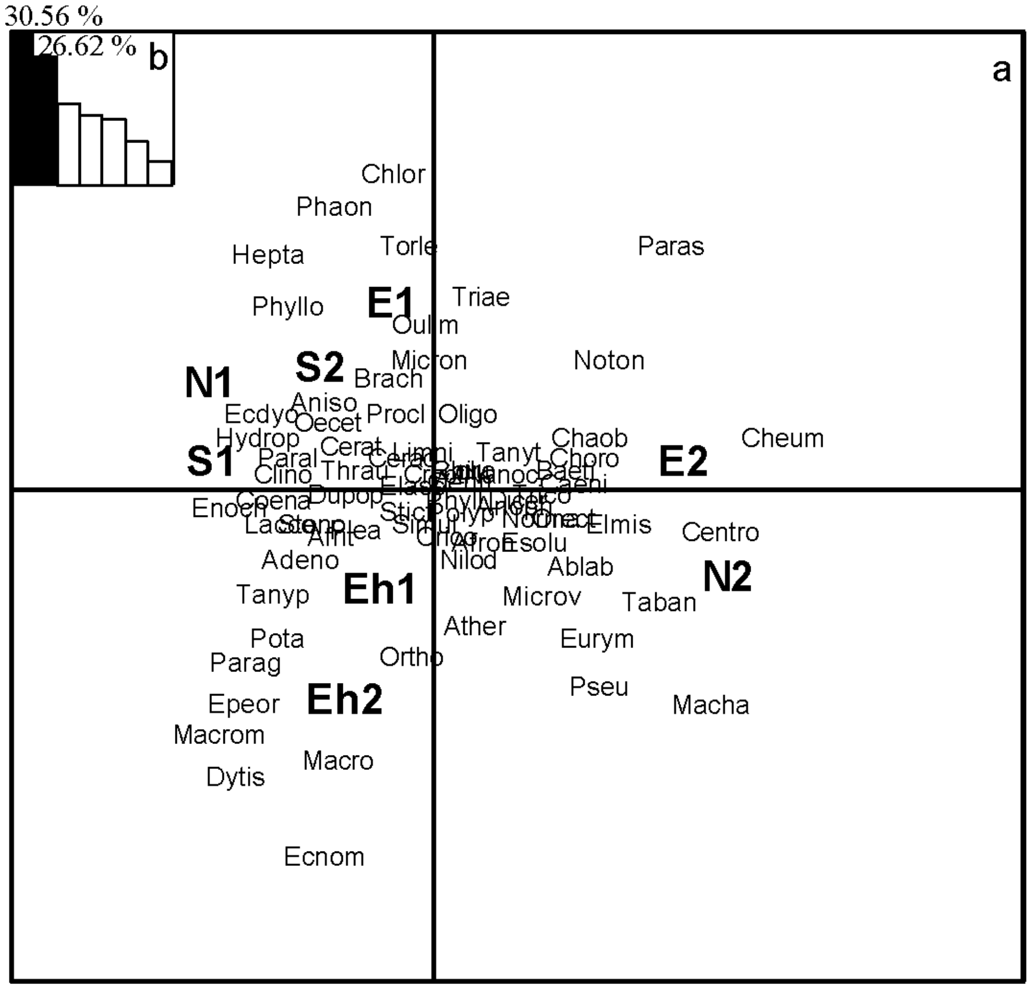

Fig. 2: Factorial Component Analysis (FCA) run on taxon presence/absence. (a) Distribution of sampling sites and taxa on the F1×F2 plane and (b) Histogram of eigenvalues. Sampling sites in bold. 1 and 2 represent upstream and downstream sites on Soumié (S) Eholié (E), Ehania (Eh) and Noé (N) rivers. See Table 2 for taxon acronyms

insects were Ephemeroptera (31 taxa) and Diptera (31 taxa), followed by Coleoptera (18 taxa). Overall, the macroinvertebrate fauna was predominantly composed of 9 taxa (*Labiobaetis gambiae*, *Polypedilum* sp., *Cricotopus* sp., *Caenis* sp., *Tanytarsus* sp., *Baetis* sp., *Simulium damnosum*, *Dicercomyzon* sp. and *Nanocladius* sp.), which were present in more than 50% of the samples. Aquatic insect richness ranged from 40 (downstream of Noé River) to 70 (upstream of Ehania River). Except for the river Noé, notable differences were not observed between the upstream and downstream sites of the other rivers (Table 2).

Factorial component analysis (Fig. 2) displayed the spatial aquatic insect distribution and revealed a strong faunistic similarity between sites, as a substantial part of the fauna was located close to the origin of the axes. The different sites therefore have a large part of their fauna in common and are differentiated by a limited number of taxa specific to each site. Nevertheless, the hierarchical cluster analysis indicated that the sites can be classified into three groups (Fig. 3). Cluster I is characterised by downstream sites on Eholié and Noé Rivers (E2, N2). Cluster II gathers both sites on Ehania River (Eh1, Eh2). Finally, cluster III was composed of the upstream sites of Eholié and Noé Rivers (E1, N1) and both sites on Soumié River (S1, S2). Overall, aquatic insect richness was significantly different between the clusters (Kruskal-Wallis test, p = 0.004). Taxa richness was significantly lower in cluster I compared to clusters II and III (Mann-Whitney test, p = 0.002) (Fig. 4).

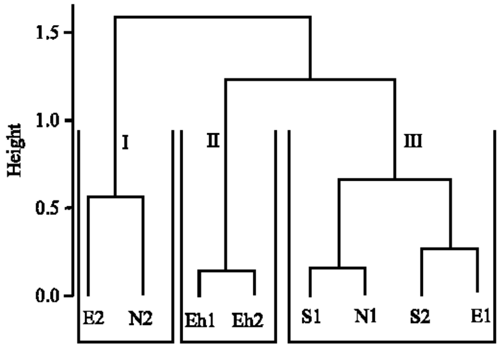

Fig. 3: Cluster dendrogram summarising similarities in aquatic insect assemblages between sampling sites using taxon presence/absence. 1 and 2 represent upstream and downstream sites on Soumié (S) Eholié (E), Ehania (Eh) and Noé (N) rivers

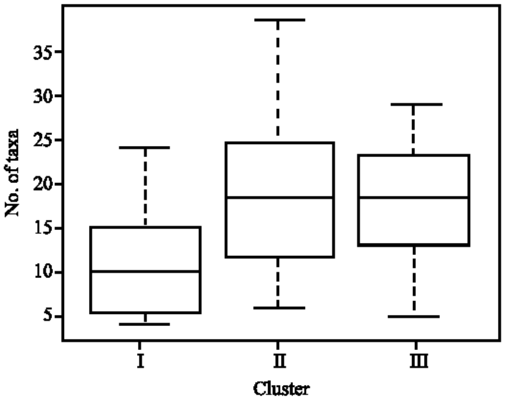

Fig. 4: Box-plots showing differences in taxonomic richness between the clusters i.dentified in Fig. 3. Box-plots were performed using the taxonomic richness of samples gathered in the clusters identified on Fig. 3. The box is corresponding to 50% of the values, the horizontal bar in the box to the median and vertical bars to the minimum/maximum values

Beta diversity: The Mantel test showed that the correlation matrix was not significant (β_w: r = 0.11, p = 0.14), indicating that dispersal of taxa was random. Nevertheless, the similarity between sites on the same river tended to be higher than that observed between sites on different rivers.

Among longitudinal gradients, β-diversity recorded in the four rivers was 0.32 (Soumié), 0.33 (Eholié), 0.23 (Ehania) and 0.51 (Noé). The highest β-diversity was found in Noé River, indicating lowest similarity between upstream and downstream sites. As for transversal gradient, β-diversity was 0.68 between upstream sites and 0.77 between downstream sites. It should be noted that, overall, the value of β-diversity was relatively lower (although differences were not significant) within sites belonging to the same basin, than between river basins.

DISCUSSION

Among the 124 taxa recorded in this study, 72 are reported for the first time from this area, while 17 were previously found by Diomandé (2001) and Diétoa (2002) in this area, 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, Diomandé (2001) described only the benthic macrofauna on Bia River, whereas Diétoa (2002) 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.

The settlement of aquatic insects of southeast Ivory Coast presented strong similarity between sites. In addition, there was no difference in β-diversity either between sites within a basin or between basins indicating that the aquatic insect taxonomic composition was homogeneous and that the four rivers thus belong to the same ecoregion. This homogeneity provides the ability to the eight sites investigated in this study to be used to develop conservation and/or biomonitoring programs based on macroinvertebrate assemblages (Meffe and Carroll, 1998). Moreover, the four rivers face little anthropogenic disturbance and could be considered as reference sites (Dallas, 2000), compared to other rivers in this region which are subjected to various anthropogenic disturbances (dams, domestic pollution) that can strongly affect macroinvertebrate assemblages.

Despite this homogeneity, the taxonomic richness differed between groups of sites. This disparity can be due to local environmental conditions, such as the size range of the substratum particles or the stability of the streambed, factors known to influence macroinvertebrate diversity (Townsend *et al*., 1997; Matthaei *et al*., 1999). Some differences can also be attributed to anthropic disturbances. For example, the downstream sites on rivers Eholié and Noé (E2, N2) gathered in cluster I have low taxonomic richness. They are probably the ones most disturbed by anthropogenic activities, as they are located close to populated areas. On the other hand, the sites gathered in clusters II and III, which are relatively exempt from disturbance, have a higher taxonomic richness.

Estimating species turnover is difficult, as few assessments of β-diversity have been made across landscapes (Harrisson *et al.*, 1992), especially in freshwater habitats (Williams *et al.*, 2003; Robson and Clay, 2005). Like Robson and Clay (2005) who calculated β-diversity for macroinvertebrates in the wetlands of a cleared agricultural landscape in south-western Victoria (Australia), we had found that β-diversity was around 0.3 in rivers Soumié, Eholié and Ehania. Such values of β-diversity indicate a high turnover in these rivers. In contrast, Noé River exhibits a lower turnover and therefore present low similarity in aquatic insect communities between sites of this river. This low similarity may be ascribable to the low taxonomic richness observed on the downstream of this river.

Comparisons made between longitudinal (sites within the same basin) and transversal (between-basin comparisons) gradients showed that, although not significantly different between sites, the turnover tends to be higher in the longitudinal gradient than in the transversal one. This may be due to elevation constraints observed between rivers and to the dispersal ability of insects (Sites *et al.*, 2003). On the other hand, river flow could facilitate the downstream drift of insects (Soderstrom, 1987).

In conclusion, the large difference observed between macroinvertebrate richness in this study and that obtained previously indicates that the species listed probably still do not cover all those actually present. Further investigations should be performed in order to complete the macroinvertebrate taxonomic list and to highlight the ecology of the dominant taxa before initiating conservation and/or biomonitoring programs. The turnover was found to be random in the study area and therefore macroinvertebrate taxonomic composition was homogeneous there. We therefore suggest that these streams be used as references in future conservation and/or biomonitoring programs.

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