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Composition, abundance and diversity of aquatic insects in fishponds of southern Ivory Coast, West Africa

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L'abondance, la densité, la biomasse et la diversité des insectes aquatiques collectés dans la colonne d'eau d'étangs piscicoles du sud de la Côte d'Ivoire ont été étudiées. Des échantillonnages mensuels ont été effectués de décembre 2007 à novembre 2008. Au total 27.381 individus répartis en 64 taxons appartenant à 25 familles et 6 ordres (Ephéméroptères, Odonate, Hémiptères, Lépidoptères, Coléoptères et Diptères) ont été récoltés. L'ordre des Hémiptères domine quantitativement et qualitativement la structure de la communauté entomologique. Les taxons *Anisops sardea* Kirkaldy 1904 (64,17%), *Plea pullula* Stål 1855 (5,87%), *Eurymetra* sp. (3,87%), *Amphiops* sp. (3,79%), *Mesovelia* sp. (3,41%) et *Cloeon bellum* Navas 1931 (2,21%) sont les plus abondants. Une variation spatiotemporelle de la densité, de la biomasse et de la diversité a été observée. Les valeurs maximales de l'abondance, de la densité et de la biomasse ont été obtenues pendant la saison des pluies à Layo. Les plus fortes valeurs de diversité de Shannon-Weaver ont été obtenues pendant la saison des pluies à Banco, Anyama I et Anyama II. En revanche, les valeurs d'équitabilité les plus élevées ont été atteintes pendant la saison sèche à Layo et Banco. Les conditions environnementales locales (température, oxygène dissous, pH, transparence, conductivité, ammonium, nitrite et phosphate) comptent pour 91,70% de la variance totale des communautés d'insectes aquatiques selon l'analyse canonique des correspondances. De même, la variation saisonnière de la composition spécifique des insectes est influencée par les changements des paramètres environnementaux dans les étangs piscicoles.
Mots-clés: insectes aquatiques, étangs piscicoles, abondance, densité, biomasse, diversité, variation spatiotemporelle, Côte d'Ivoire

Abundance, density, biomass, and diversity of aquatic insects collected in water column from fishponds in southern Ivory Coast were studied. Monthly samplings have been conducted from December 2007 to November 2008. A total of 27,381 individuals belonging to 64 taxa, 25 families and 6 orders (Ephemeroptera, Odonata, Hemiptera, Lepidoptera, Coleoptera, and Diptera) were collected. Among these six orders, Hemipterans dominated quantitatively and qualitatively aquatic insect's community structure. The most abundant species were *Anisops sardea* Kirkaldy 1904 (64.17%), *Plea pullula* Stål 1855 (5.87%), *Eurymetra* sp. (3.87%), *Amphiops* sp. (3.79%), *Mesovelia* sp. (3.41%) and *Cloeon bellum* Navas 1931 (2.21%). A spatiotemporal variation was observed for the different recorded parameters (density, biomass, and diversity). The maximum abundance, density, and biomass were recorded during the rainy season in the station of Layo. The Shannon-Weaver index indicated that the highest diversity of aquatic insects was obtained during the rainy season in the stations of Banco, Anyama I and Anyama II. In contrast, evenness reached maximum values during the dry season in the stations of Layo, and Banco. Local environmental conditions (i.e. temperature, dissolved oxygen, pH, transparency, conductivity, ammonium, nitrite and phosphorus) accounted for 91.70% of variation in aquatic insect assemblages using canonical correspondence analysis (CCA). Seasonal trends in aquatic insect community composition were also related to changes in environmental characteristics of the fishponds.
Keywords: aquatic insects, fishponds, abundance, density, biomass, diversity, spatiotemporal variation, Ivory Coast

1. INTRODUCTION

Ponds are small shallow, natural or man-made water bodies defined as wetlands by the Ramsar Convention (Céréghino *et al*., 2008). Studies have revealed their importance for the conservation of biodiversity (Pyke, 2005; Scheffer *et al*., 2006) because, despite of their small size, they contribute to regional diversity. Thus, ponds challenge conventional approaches to conversation biology, where much attention has been directed towards large-scale ecosystems (Céréghino *et al*., 2008). It is now well established that pond management and conservation is closely related to our knowledge of the biodiversity and ecology of the biota they host, and to their usefulness in terms of ecological and economic service (Ruggiero *et al*., 2008). Fishpond ecosystems are important hotspots for macrofauna biodiversity (Apinda-Lognouo, 2007).

There is limited knowledge on aquatic insect assemblages of natural or artificial ponds ecosystems. Insects play an important role in aquatic ecosystems functioning (Dunbar *et al*., 2010). They are an important component of invertebrate assemblages in aquatic ecosystem where they are a controlling group in food webs. At the larval stage, they constituted the principal nutritive fauna of fish (Minshall, 2003; Tachet *et al.,* 2003). Many aquatic insect species are strictly seasonal and prefer only a particular set of habitats (Bonada *et al*., 2005) and they are good indicators in terms of anthropogenic disturbance and habitat quality (Clarke *et al*., 2002; Varandas & Cortes, 2010). Factors affecting the aquatic insect community assembly have long been a topic of interest to ecologists and conservationists. Many researchers have significantly contributed to our understanding of insect taxonomic diversity and abundance in tropical aquatic ecosystem (Dejoux *et al*., 1981; Diétoa, 2002; Kouadio *et al*., 2008), including in their work habitat association, effect of disturbance and area clearance (Stazner *et al*., 1984), seasonal abundance and density patterns (Elouard & Lévêque, 1977), and conservation of rivers ecosystem in Ivory Coast (Edia, 2008; Edia *et al*., 2010). The identification of species and their distribution patterns provide more information for monitoring and conserving these ecosystems.

In order to assess whether fishponds contribute to the maintenance of regional freshwater invertebrate diversity, we determined the abundance, density, biomass, and diversity of aquatic insect communities and their relation to environmental variables in fishponds of southern Ivory Coast.

2. MATERIAL AND METHODS

This study was undertaken in five fish farms in the southern region of Ivory Coast, characterized by a dry and a rainy season. The dry season extends from December to March and from August to September while the rainy season extends from April to July and from October to November. Five sites were sampled: Aquaculture Experiment Station of Layo (05°19'N; 04°18'W), fish farms of Banco (05°23'N; 04°03'W), Azaguié (05°39'N; 04°05'W), Anyama I (05°33'N; 04°03'W) and Anyama II (05°34'N; 04°02'W) (**Figure 1**). They were assigned to habitat types according to environmental and ecological features. Banco site is located in the National Park of Banco which is mainly constituted of primary forests. In Azaguié, Anyama I and Anyama II, ecosystems are constituted by agricultural landscape, while at Layo site, immediate environment is characterized by habitations. In each site, three ponds were randomly selected for this study. The main water supplies were different in the sites: ponds in Anyama I and Azaguié were fed respectively by a man-made lake and a stream, ponds in Banco by Banco River, ponds in Anyama II by groundwater, and ponds in Aquaculture Experimental Station of Layo by coastal aquifer. Ponds located in the latter site were fed by brackish water (salinity ranging from 0 $mg.L^{-1}$ in the rainy season to 10 $mg.L^{-1}$ in the dry season, Legendre *et al*., 1987). In the four others sites, ponds were supplied with fresh water. The ponds in all sites were permanent, shallow (depth<1 m) and contained tilapia *Oreochromis niloticus* (L. 1758). Ponds area varied between 280 m^2 and 350 m^2. On each sampling date, environmental variables such as transparency, temperature, pH, dissolved oxygen and conductivity were measured *in situ* between 08.00 am and 10.00 am. Water temperature, pH and electric conductivity were measured using a multiparameter digital meter (WTW pH/Cond 340i). Dissolved oxygen concentration was measured with a WTW Oxi 92 oxygen meter and water transparency was determinate using a 20-cm-diameter Secchi disk. Water samples were collected on every sampling

day, filtered through GF/C Whatman® filters, frozen upon arrival at laboratory. Analyses of dissolved inorganic nutrients: ammonium (NH_4^+), nitrite (NO_2^-), and phosphorus (PO_4^{3-}) were carried out according to Grasshoff *et al.* (1983).
Sampling for macroinvertebrates was done monthly between December 2007 and November 2008. Six water column samples in each pond per site were collected using a 350 µm mesh hand-net. The collected organisms were emptied into white enamel trays for sorting by passing the samples through a 300 µm sieve. The six samples were pooled and the remaining materials were preserved in plastic bottles containing 10% formalin. In the laboratory, specimens were sorted and identified under a stereo binocular microscope to the lowest possible taxonomic level, by use of systematic and classification keys (Dejoux *et al.*, 1981; de Moor *et al.*, 2003a, 2003b; Tachet *et al.*, 2003). Insects were counted and numbers of each species were expressed as organisms per m^2. For each sampling date and site, mean macroinvertebrate metric scores and standard deviation were calculated using a pool of six mesh hand-net replicate samples. Mean densities (individuals.m^{-2}) were calculated for each sampling date and for the overall study period. Mean biomass (dry weight; mg.m^{-2}) was estimated after desiccation to constant weight for 24 h at 60 °C according to Mathooko (2001). We evaluated the Shannon-Weaver's diversity (H') and evenness indexes for each month and sampling station.
Before performing the comparison test, the normality of data was checked by the Kolmogorov-Smirnov test. Data were log10 (X+1) transformed prior to analysis. A comparison of the data collected at different stations was made using one-way ANOVA and Tukey's *post hoc* test. Differences between seasons were tested using a t-test. Relationships between the distribution of aquatic insects and environmental variables in all sampling stations were determined by Canonical Correspondence Analysis (CCA) using CANOCO 4.5 software. Taxa which represented at least 0.5% of the total abundance were included in the analysis. These taxa were considered as principal taxa. This has been done to minimize the influence of rare taxa.

3. RESULTS

The variations of environmental parameters are given in **Table 1**. The electric conductivity varied from 35.85 ± 2.88 µs.cm^{-1} (Banco) to 3037.83 ± 2980.25 µs.cm^{-1} (Layo). Water temperature ranged between 27.20 ± 0.60 °C (Banco) and 28.97 ± 1.10 °C (Azaguié). The lowest dissolved oxygen values were recorded in Banco (4.18 ± 1.15 mg.L^{-1}) and the highest values were observed in Anyama I (6.33 ± 0.44 mg.L^{-1}). Banco presented low values of pH (6.75 ± 0.19), while high values (7.08 ± 0.12) were recorded in Anyama I. Water transparency fluctuated between 21.65 ± 6.84 cm (Layo) and 30.14 ± 4.25 cm (Banco). Nitrite values varied between 0.62 ± 0.52 mg.L^{-1} (Anyama I) and 1.26 ± 0.84 mg.L^{-1} (Layo). Phosphorus oscillated between 1.09 ± 0.69 mg.L^{-1} (Anyama I) and 2.47 ± 1.44 mg mg.L^{-1} (Layo). Banco ammonium was significantly greater compared to other stations. Seasonal variations showed that the mean values of temperature, dissolved oxygen and electric conductivity were low during the rainy season in all stations. By contrast, the mean values of pH obtained in all stations were lower in the dry season. Concerning nitrites, the mean values recorded in Layo and Banco stations were lower during the rainy season. Ammonium and phosphorus mean values recorded in all stations were higher during the dry season except for Banco and Anyama I stations.
A total of 27,381 aquatic insects belonging to 64 taxa, 25 families and 6 orders (Ephemeroptera, Odonata, Hemiptera, Lepidoptera, Coleoptera and Diptera) were collected. However, 78.12% of the total aquatic insect taxa richness was attributed to three taxonomic groups that included Coleoptera (21 taxa), Hemiptera (19 taxa), and Diptera (10 taxa). Hemiptera, with 86.33% of the total abundance, dominated quantitatively in all sampling stations. The contribution of the Hemiptera *Anisops sardea* Kirkaldy 1904 to total abundance was considerably higher in Azaguié (5,256 ind.), Anyama II (4,696 ind.), Anyama I (4,074 ind.), and Layo (3,093 ind.) than in Banco (453 ind.). Consequently, the total abundance ranged from 4,304 ind. in Banco to 6,233 ind. in Azaguié (**Table 2**). Nineteen taxa were common to all the stations: the Ephemeroptera *Cloeon bellum* Navas 1931, *Cloeon smaeleni* Lestage 1924, and *Cloeon gambiae* Gillies 1980, the Odonata *Pseudagrion whellani* Pinhey 1956 and *Pseudagrion* sp., the Hemiptera *Diplonychus* sp., *Eurymetra* sp., *Limnogonus chopardi* Poisson

1941, *Micronecta* sp., *A. sardea*, *Anisops* sp., Notonectidae, *Mesovelia* sp. and *Ranatra parvipes* Signoret 1880, the Coleoptera *Hydrochara rickseckeri* (Horn 1895) and *Canthydrus xanthinus* Guignot 1948, and the Diptera *Chironomus imicola* Kieffer 1913, *Nilodorum fractilobus* Kieffer 1923 and *Tanypus fuscus* Freeman 1955.

Table 3 summarizes variations of the number of taxa, density, biomass, and diversity indexes among stations. Forty-three taxa were recorded in Layo, 41 taxa in Banco, 40 in Anyama II, 38 in Azaguié and 33 taxa in Anyama I. Over the entire study period, insect density and biomass showed significant fluctuations among stations ($F_{4, 180}$=3.09, P=0.01 and $F_{4, 180}$=44.74, P<0.01, respectively). Density and biomass were significantly lower in Banco (253.83 ± 104.36 ind.m^{-2} and 4.36 ± 1.28 mg.m^{-2}, respectively) compared to Azaguié (367.59 ± 95.56 ind.m^{-2} and 21.62 ± 5.18 mg.m^{-2}, respectively). Shannon-Weaver (H'=3.03; $F_{4, 180}$=116.91, p=0.00) and evenness (E=0.80; $F_{4, 180}$=150.85, p=0.00) indexes indicated significant difference between the diversity of aquatic insects in all stations (**Table 3**). Shannon-Weaver and evenness reached maximum values at Banco station. By contrast, the lowest values of Shannon-Weaver diversity (H'=0.95) and evenness (E=0.32) indexes were recorded in Azaguié station (**Table 3**).

Seasonal variations of abundance, density, biomass and diversity indexes between dry and rainy seasons in each station were showed in **Table 4**. No significant seasonal variations of abundance, density and biomass were found in a single station except in Layo where abundance, density and biomass were higher during the rainy season. In contrast, the seasonal variations of Shannon-Weaver diversity and evenness indexes were highly heterogeneous. Shannon-Weaver diversity index was higher during the rainy season in three stations Banco, Anyama I and Anyama II, whereas the evenness values were higher in the dry season in both stations of Layo and Banco (**Table 4**).

The results of redundancy analysis revealed that the relationships between insect's taxa and their habitat conditions follow mainly the first two axes (**Figure 2**). These two axes accounted for 91.70% of the total variance. Conductivity, nitrite and phosphorus were positively correlated to axis I. Temperature, dissolved oxygen and pH were negatively correlated to this axis. High values of these parameters were recorded in Azaguié, Anyama I and Anyama II. These stations were characterized by *P. whellani*, *R. parvipes*, *C. smaeleni, L. chopardi*, *Anisops* sp., *Tanypus fuscus, Ceriagrion* sp., *H. ricksekeri* and *Micronecta* sp. High values of conductivity and nitrite were recorded in Layo, which was characterized by *Canthydrus minutus* Régimbart 1895. The axis II opposed Anyama I, Azaguié and Anyama II in negative coordinates to Banco (in positive coordinates) where *C. bellum, Mesovelia* sp., *Amphiops* sp., and *Plea pullula* Stål 1855 were mainly represented. These taxa were associated to high values of transparency and ammonium.

4. DISCUSSION

Sixty-five aquatic insect taxa were reported in the different stations. Six of them (*C. bellum*, *C. gambiae*, *Cloeon smaeleni*, *Pseudobagous* sp., *Bagous* sp., *Macroplea* sp.) were recorded for the first time in Ivory Coast and complete the list of insect species from Ivorian aquatic ecosystems. The present study shows that insect fauna of fishponds was dominated by Hemipterans that are typical of many freshwater systems (Arslan *et al*., 2010). This order represented 86.36% of total abundance of aquatic insects collected in this study. In addition, the large spatial variation of the aquatic insect's abundance observed between Azaguié and Banco was consequently due to the heterogeneous distribution of Hemiptera in both stations. This group was mainly represented by the Hemipterans *A. sardea, P. pullula, Eurymetra* sp., and *Mesovelia* sp. in this study. Previous studies showed that the species of the genus *Anisops* have worldwide distributions and commonly occur in freshwater standing systems (Mousavi, 2002; Arslan *et al*., 2010). Similarly, in this current study, *A. sardea* was the most abundant species recorded in all stations except Banco where *P. pullula* was more abundant. *A. sardea* has been reported as being ecological tolerant (Apinda-Lognouo, 2007; Florencio *et al*., 2009) and having extensive geographical range (Çamur-Elipek *et al*., 2010). This assertion was supported by the strong and significantly positive correlations observed between environmental variables and *A. sardea* in Anyama I, Anyama II and Azaguié stations. In addition, Shannon-Weaver diversity and evenness indexes recorded in these stations were lower irrespective of seasonal variations and could be explained by the high species dominance of *A. sardea*. The settlement structure of Anyama I, Anyama II and Azaguié stations is marked by a small number of species that dominate quantitatively. According to Blondel (1979) this situation is characteristic of disturbed habitats. On the other hand, *Aulonogyrus* sp., *Libellula* sp., *Hydrocoptus simplex* Guignot 1954, *Laccophilus vermiculosus* Gerstaecker 1867, and *Yola tuberculata* Régimbart 1895 were not particularly abundant during this study, and accounted for only one specimen of each taxa. Their small number from the fishponds in the sampling stations may have been caused in part by the environmental conditions in these ponds (Jana *et al*., 2009).

When the abundance, density and biomass of aquatic insects are evaluated according to different seasonal and spatial levels, it appeared that these parameters did not vary in the stations except in Layo where all parameters were higher during the rainy season. As mentioned in previous studies, the little variations in abundance, density and biomass observed in both rainy and dry seasons could be related to the low seasonal variation of environmental conditions in the four stations (Florencio *et al.,* 2009; Jana *et al*., 2009). Also, an absence of seasonal change in abundance of benthic invertebrates in a tropical stream on Bougainville Island was reported by Yule & Pearson (1996). They suggested that all species exhibited asynchronous life cycles with continuous hatching, growth and insect emergence. Inversely, the seasonal variations of aquatic insect parameters in the Layo station were mainly due the high values of conductivity and nitrite recorded during the rainy season compare to dry season. In addition, positive correlation was observed between *C. bellum*, *Mesovelia* sp., *Amphiops* sp. and ammonium. These species were the most abundantly recorded in both Banco and Layo stations. Moreover, some environmental variables such as temperature, conductivity, and dissolved oxygen are important regarding the seasonal variation of aquatic insect density and biomass. According to Ross *et al*. (1982), temperature is one of the most important environmental factors controlling aquatic insect density. In this study, the pattern distribution according to environmental variables indicates that *P. whellani*, *R. parvipes*, *L. chopardi*, *C. smaeleni*, *Anisops* sp., *Tanypus fuscus*, *Ceriagrion* sp., *H. ricksеckeri* and *Micronecta* sp. were associated to high value of pH, temperature, and dissolved oxygen. In southern Ivory Coast, Edia (2008) found significant relationships between species composition and pH, temperature, and dissolved oxygen in the Soumié, Ehania, Tanoé and Eholié rivers. A similar result was observed by Diomandé *et al*. (2009) in Bia River (southern Ivory Coast) and Ogbeibu (2001) who observed a significant positive correlation between density and water temperature in temporary pond in Okomu Forest Reserve.

CONCLUSION

In conclusion, the present study reports 64 aquatic insect taxa in the different inventoried stations. Six of these taxa were recorded for the first time in Ivory Coast aquatic ecosystem. Hemiptera was the most diversified group. This group was numerically the most abundant and dominated also aquatic insect biomass in fishponds. Importance of abiotic factors in distribution of aquatic insects hosted by farm ponds was also shown. Our results support the ideas that farm ponds make a significant contribution to freshwater biodiversity and may have substantial conservation value. Consequently, farm ponds should be protected from pollution. Data on the spatial and temporal aquatic insect assemblages may help in planning management efforts, such as the creation or restoration of ecosystems.

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(33 réf.)

Table 1 : Seasonal variation of the environmental variables (mean ± (SD)) in the sampling stations

Parameters	**Stations**									
	Layo		**Banco**		**Azaguié**		**Anyama I**		**Anyama II**	
	DS	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**
Secchi disk transparency (cm)	23.26[a] (7.42)	20.05[a] (5.99)	28.73[a] (4.66)	31.55[b] (3.38)	22.63[a] (9.07)	21.47[a] (6.14)	22.63[a] (9.07)	21.47[a] (6.14)	22.75[a] (4.53)	22.78[a] (3.04)
Temperature (°C)	28.6[a] (0.72)	28.07[a] (1.36)	27.41[b] (0.41)	26.98[a] (0.69)	29.31[a] (0.97)	28.63[a] (1.58)	28.88[a] (1.17)	28.71[a] (0.98)	29.15[b] (0.74)	28.46[a] (0.90)
Dissolved oxygen ($mg.L^{-1}$)	6.02[b] (1.55)	5.08[a] (0.83)	4.81[b] (0.88)	3.56[a] (1.07)	5.84[a] (0.52)	5.58[a] (0.77)	6.57[a] (0.38)	6.08[b] (0.36)	6.33[b] (0.27)	6.00[a] (0.44)
pH	6.91[a] (0.11)	6.95[a] (0.11)	6.68[a] (0.18)	6.83[b] (0.18)	6.87[a] (0.11)	6.94[b] (0.09)	7.02[a] (0.13)	7.14[b] (0.09)	7.02[a] (0.19)	7.05[a] (0.14)
Conductivity ($\mu s.cm^{-1}$)	4604.61[b] (3485.66)	1471.05[a] (968.53)	36.75[a] (2.83)	34.95[a] (2.70)	40.05[a] (2.84)	36.04[b] (4.20)	72.18[a] (10.62)	70.26[a] (17.17)	52.31[a] (16.18)	45.97[a] (17.00)
Nitrite ($mg.L^{-1}$)	1.54[b] (1.07)	0.99[a] (0.38)	1.15[a] (1.02)	0.70[a] (0.46)	0.99[a] (0.62)	1.05[a] (0.50)	0.55[a] (0.61)	0.70[a] (0.54)	1.03[a] (0.45)	1.09[a] (0.44)
Ammonium ($mg.L^{-1}$)	0.14[a] (0.20)	0.29[b] (0.21)	0.37[a] (0.34)	0.20[a] (0.25)	0.07[a] (0.08)	0.24[b] (0.32)	0.14[a] (0.12)	0.18[a] (0.26)	0.07[b] (0.08)	0.16[a] (0.19)
Phosphate ($mg.L^{-1}$)	2.54[a] (0.90)	2.41[a] (1.86)	2.34[a] (0.81)	1.81[a] (0.84)	2.39[a] (0.92)	1.70[a] (1.38)	0.92[a] (0.56)	1.25[a] (0.78)	2.41[b] (0.72)	1.78[a] (0.74)

DS: dry season; RS: rainy season.
[a, b]: letters on the same line show the difference between seasons at the same station as regards the parameter indicated.

Table 2 : List and abundance of aquatic insects identified in the sampling stations
La= Layo; Ba=Banco; Az= Azaguié; AnI= Anyama I; AnII= Anyama II

Orders	**Families**	**Taxa**	**Code**	**Stations**				
				La	**Ba**	**Az**	**AnI**	**AnII**
Ephemeroptera	Caenidae	*Caenis* sp.	Caeni	0	0	0	6	5
	Baetidae	*Cloeon bellum*	Clobe	303	235	105	117	102
		Cloeon smaeleni	Cloma	46	72	14	30	17
		Cloeon gambiae	Cloga	80	177	61	43	48
Odonata	Coenagrionidae	*Ceriagrion* sp.	Ceriag	15	32	13	7	0
		Pseudagrion whellani	Pwel	45	40	48	64	46
		Pseudagrion sp.	Pseu	11	20	29	18	26
		Ischnura sp.	Ichnu	19	0	1	0	0
		unidentified	Coena	0	0	2	0	6
	Libellulidae	*Libellula* sp.	Libel	1	0	0	0	0
		Crocothemis sp.	Croco	2	5	0	3	1
		Brachythemis sp.	Brach	0	0	2	0	0
		Pantala flavescens	Pafla	15	32	13	7	0
Hemiptera	Belostomatidae	*Appasus* sp.	Appas	102	86	8	0	2
		Diplonychus sp.	Diplo	159	38	65	8	38
	Gerridae	*Eurymetra* sp.	Eurym	68	288	151	339	215
		Limnogonus chopardi	Limno	77	71	75	109	132
		Naboandelus sp.	Naboa	1	0	1	1	1
	Corixidae	*Micronecta* sp.	Micro	45	131	95	42	17
		Stenocorisea protrusa	Stepr	18	3	10	0	5
		Sigara sp.	Sigar	0	0	3	0	0
	Notonectidae	*Anisops sardea*	Anisa	3093	453	5256	4074	4696
		Anisops sp.	Aniso	20	93	15	18	44
		Enithares sp.	Enith	10	2	0	8	1
		unidentified	Noton	12	136	21	35	21
	Naucoridae	*Naucoris* sp.	Nauc	13	2	0	0	0
	Pleidae	*Macrocoris flavicolis*	Maflaf	0	20	0	3	0
		Plea pullula	Plea	263	1324	21	0	0
	Mesoveliidae	*Mesovelia* sp.	Meso	398	375	47	184	34
	Veliidae	*Rhagovelia reitteri*	Rhago	0	3	1	4	0
	Nepidae	*Laccotrephes ater*	Lacot	0	0	0	1	3
		Ranatra parvipes	Ranap	125	123	88	127	76
Lepidoptera	Pyralidae	unidentified	Pyral	28	1	0	0	1
Coleoptera	Hydrophilidae	*Amphiops* sp.	Amp	266	329	3	0	8
		Hydrochara rickseckeri	Hydri	15	26	14	15	6
		Hydrobius sp.	Hydrob	5	0	0	0	0
	Dytiscidae	*Canthydrus minutus*	Canth	341	0	0	0	0
		Canthydrus xanthinus	Canxa	91	17	19	4	16
		Cybister tripunctatus	Cybis	15	0	2	0	0
		Yola tuberculata	Yotub	1	0	0	0	0
		Hydrocanthus micans	Hydmi	22	0	0	0	0
		Hydrocoptus simplex	Hydsi	1	0	0	0	0
		Laccophilus vermiculosus	Lacov	0	0	1	0	0
		Hyphydrus sp.	Hyphy	0	2	0	0	0

Table 2 : extended

Orders	Families	Taxa	Code	Stations				
				La	**Ba**	**Az**	**AnI**	**AnII**
	Spercheidae	*Spercheus ceryisi*	Sperc	0	0	2	0	0
	Gyrinidae	*Orectogyrus* sp.	Orect	0	0	0	13	70
		Aulonogyrus sp.	Aulon	0	0	0	0	1
	Elmidae	*Potamodytes* sp.	Potam	0	0	1	0	2
		Limnius sp.	Limnu	39	12	0	1	1
		Potamophilus sp.	Potap	1	0	0	0	0
		Esolus sp.	Esolu	0	4	0	1	0
	Curculionidae	*Pseudobagous* sp.	Pseub	9	6	1	0	3
		Bagous sp.	Bagou	8	3	0	1	0
	Chrysomelidae	*Macroplea* sp.	Macro	0	6	0	0	0
Diptera	Chironomidae	*Nilodorum fractilobus*	Nifra	8	5	6	10	6
		Nilodorum brevipalpis	Nibre	0	0	11	0	2
		Tanypus fuscus	Tafus	1	105	15	14	14
		Clinotanypus claripennis	Clino	0	0	0	0	7
		Chironomus imicola	Chimi	1	1	12	6	8
		Polypedilum sp.	Polyp	4	1	0	0	0
		Stictochironomus sp.	Sticto	0	21	11	1	1
	Ceratopogonidae	*Ceratopogon* sp.	Cerat	0	0	0	0	11
	Chaoboridae	*Chaoborus anomalus*	Chano	0	2	0	0	20
	Culicidae	*Culex quinquefasciatus*	Cufat	38	30	3	2	0
Total 6	**25**	**64**		**5820**	**4304**	**6233**	**5309**	**5715**

Table 3 : Spatial variation of Number of taxa, density, biomass, Shannon-Weaver diversity and evenness indexes among stations (mean ± (SD))

Parameters	Stations				
	Layo	**Banco**	**Azaguié**	**Anyama I**	**Anyama II**
Number of taxa	43	41	38	33	40
Density (ind.m^{-2})	343.24^{ab} (110.90)	253.83^{a} (104.36)	367.59^{b} (95.56)	313.10^{ab} (119.16)	337.04^{ab} (118.60)
Biomass (mg.m^{-2})	15.73^{b} (3.02)	4.36^{a} (1.28)	21.62^{c} (5.18)	17.55^{b} (4.18)	19.55^{bc} (4.93)
Shannon-Weaver	2.25^{b} (0.66)	3.03^{c} (0.20)	0.95^{a} (0.47)	1.18^{a} (0.38)	1.03^{a} (0.07)
Evenness	0.63^{c} (0.07)	0.80^{d} (0.06)	0.32^{a} (0.07)	0.41^{b} (0.07)	0.35^{ab} (0.07)

^{a,b,c,d}: on the same line show the difference between stations as regards the parameter indicated

Table 4 : Seasonal variation in abundance, density, biomass, Shannon-Weaver diversity and evenness indexes of aquatic insects in the sampling stations (mean and (SD)). DS: dry season; RS: rainy season

Parameters	**Stations**									
	Layo		**Banco**		**Azaguié**		**Anyama I**		**Anyama II**	
	DS	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**
Abundance (ind.)	132.77^{a} (61.78)	190.55^{b} (71.37)	106.22^{a} (64.71)	132.88^{a} (88.17)	170.72^{a} (40.40)	175.55^{a} (50.25)	136.38^{a} (41.12)	158.50^{a} (67.19)	150.72^{a} (51.70)	166.77^{a} (60.12)
Density (ind.m^{-2})	281.90^{a} (131.17)	404.57^{b} (157.69)	225.52^{a} (137.40)	282.14^{a} (147.19)	362.46^{a} (85.79)	372.72^{a} (106.70)	289.57^{a} (87.31)	336.63^{a} (106.95)	320.00^{a} (109.77)	354.09^{a} (127.64)
Biomass (mg.m^{-2})	13.52^{a} (3.24)	17.94^{b} (4.11)	3.93^{a} (2.07)	4.79^{a} (2.46)	21.07^{a} (5.06)	22.16^{a} (5.39)	17.91^{a} (5.31)	17.19^{a} (5.09)	18.35^{a} (6.56)	20.76^{a} (7.27)
Shannon-Weaver	2.37^{a} (0.58)	2.14^{a} (0.74)	2.27^{a} (0.12)	3.09^{b} (0.29)	0.98^{a} (0.31)	0.93^{a} (0.64)	0.94^{a} (0.37)	1.42^{b} (0.40)	0.69^{a} (0.33)	1.27^{b} (0.36)
Evenness	0.75^{b} (0.11)	0.63^{a} (0.11)	0.88^{b} (0.05)	0.80^{a} (0.03)	0.33^{a} (0.06)	0.32^{a} (0.09)	0.35^{a} (0.06)	0.41^{b} (0.08)	0.34^{a} (0.08)	0.35^{a} (0.07)

$^{a, b}$: letters on the same line show the difference between seasons at the same station as regards the parameter indicated.

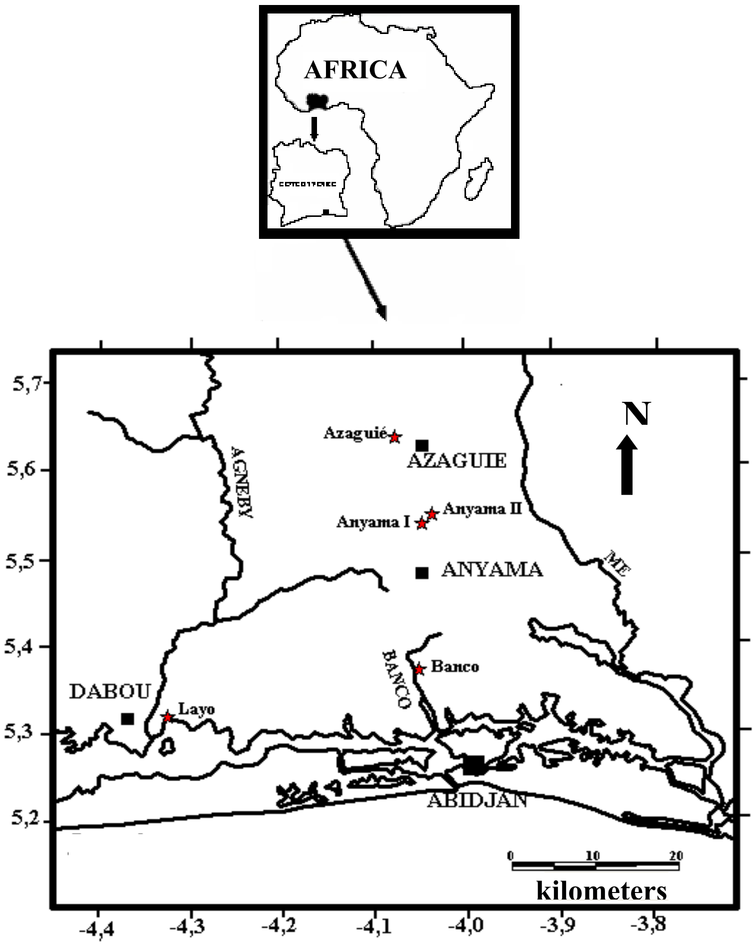

Figure 1 : Location of the study area showing the sampling stations

Legend :

■ Towns

★ Stations

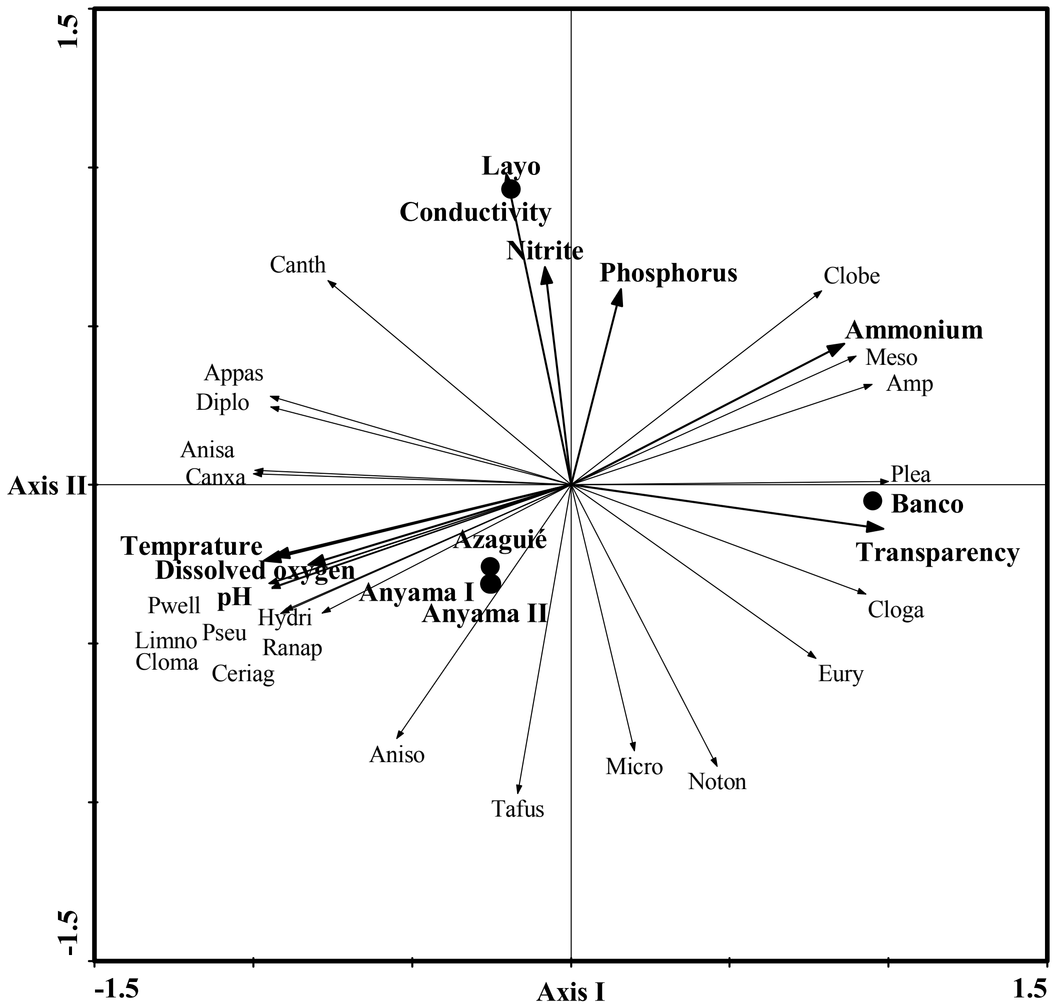

Figure 2 : Canonical correspondence analysis showing correlation between environmental variables and principal taxa collected