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Diversity and community structure of a non-stocked pond insects of a tropical forest: the National Park forest of Banco, Côte d'Ivoire, West Africa.

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ABSTRACT

The aim of this study was to determine diversity and community structure of aquatic insect in a non stocked pond. Monthly samplings have been conducted from December 2007 to November 2008 in a non stocked fish farm pond located in the National park of Banco (southern Côte d'Ivoire). In the pond, water column and sediment were monthly collected. Environmental variables such as transparency, temperature, pH, dissolved oxygen, TDS and conductivity were measured *in situ*. Water samples were taken and conducted to the laboratory where analyses of dissolved inorganic nutrients were carried out. In the pond, four sampling sites were chosen on the four sides (A, B, C and D). In each site samples were collected in water column using a 350 µm mesh hand-net and in the sediment using a van Veen grab. A total of 62 taxa belonging to 30 families and 8 orders were recorded. Aquatic insects fauna richness is clearly dominated by Heteroptera, Diptera and Coleoptera. *Plea pullula*, *Anisops sardea*, *Nilodorum fractilobus*, *Stictochironomus* sp. and *Tanypus fuscus* were the dominant taxa. The highest values of Shannon-Wiener diversity and Evenness indexes were recorded at site A and site B respectively. Site A recorded the highest value of Margalef index. Insect community structure was visualized using Canonical Correspondence Analysis to show the affinities of each species for selected environmental parameters. This study revealed that water quality of the pond is good as supported by the values of biological indices and by presence of insect of orders Ephemeroptera and Trichoptera.

Keywords: aquatic insects, non-stocked pond, diversity, community structure, Banco, Côte d'Ivoire.

.1-INTRODUCTION

Ponds are an important component of the freshwater environment and are known to support rich plant and macroinvertebrate communities (Collinson *et al.* 1995, Nicolet *et al.* 2004) and provide a habitat for a variety of uncommon plant and macroinvertebrate taxa (Collinson *et al.* 1995, Nicolet *et al.* 2004, Bilton *et al.* 2009). Ponds have recently been recognized as important habitats for the maintenance of biodiversity (Oertli *et al*., 2005). Scientific interest in these freshwater bodies has increased over the past decade (Apinda-legnouo, 2007). Several studies on ponds and their diversity have been made by many authors. In North America, for example, Hoffman *et al*. (2004) focused on mountain ponds and lakes for dragonflies (Odonata), macroinvertebrates, fish, amphibians, plankton and macrophytes. In Asia, Jana *et al*. (2009) worked on aquatic insects. In Europe, Angelibert *et al*., (2004) investigated pond for macroinvertebrates, zooplankton and macrophytes, Nicolet *et al.* 2004 surveyed temporary ponds for macroinvertebrates and macrophyte. Bazzanti *et al*. (2000)

described temporary and permanent ponds macroinvertebrates. Della Bella *et al*. (2005) investigated Mediterranean ponds for macroinvertebrates. In Southern Africa, Weir (1972) worked in Zimbabwe for insects and fish, Apinda-Legnouo (2007) focused on ponds for aquatic beetles and bugs in South Africa. In West Africa as a whole, little is known about aquatic macroinvertebrates of pond. In Côte d'Ivoire, the few ponds studies are those of Bony *et al*. (2008) and Yapo *et al*. (2007, 2012, 2013, 2014a, 2014b, 2015), Edia (2013). Relativly, little attention have been given to the insect fauna of pond in Côte d'Ivoire. In this country, available literature concerning macroinvertebrates from ponds located in conservation areas is scarce. The Banco National Park forest plays an important role in the city of Abidjan as part of the treatment cleared of gas producted by many vehicles and factory of the city. Banco National Park represents the main drinking water reservoir, providing about 40% of needs. It has strong environmental and social potential and is a reservoir of data for science, education and culture. This park is also important in this regard as it is a place of conservation of animal and plant species. Despite this forest is located in Abidjan, where access is not as difficult, very few studies have been conducted in it (Bony *et al*., 2008; Camara *et al*., 2012; Yapo *et al*., 2013; Yapo *et al*., 2014a; Yapo *et al*., 2014b; Yapo *et al*., 2015), very little attention has been given to its animal diversity. Studies should be encouraged in this forest. The aims of this study were (i) to inventory the insect fauna community of the Banco National Park non-stocked pond; (ii) to describe the structure of this community; and (iii) to investigate the relationships between insect's fauna richness and environmental variables.

2. MATERIAL AND METHODS

2.1 Study Site

This study was undertaken in a fish farm located in the Banco National Park in the centre of Abidjan, in the southern region of Côte d'Ivoire, characterized by two seasons (dry and rainy seasons). 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. Banco National Park is mainly constituted of primary forests. Air temperature in this park average 27°C, with an annual precipitation of approximately 1600–2500 mm (Kouamé *et al*., 2008). The studied pond was fed by Banco River. It was permanent and shallow (depth<1 m). Pond area was 1000 m^2. Bottom sediment was mostly composed by mud. The pond contained some macrophytes as water Hyacinths, *Eichhornia crassipes*. It not contained fish.

2.2 Sampling Procedures

Sampling for aquatic insects was done monthly between December 2007 and November 2008. In the pond, water column and sediment were monthly collected. In the pond, four sampling sites (A, B, C, D) were chosen on the four sides of the pond. In each site, one water column sample was 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. In each site, six sediment replicates were collected using a van Veen grab of 0.09 m^2 internal area. The six samples were pooled, sieved through 1 mm aperture size sieve. 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; Gattoliat, person communication). Insects

were counted and numbers of each species were expressed as organisms per m^2. Mean densities (individuals.m^{-2}) were calculated for each sampling date and for the overall study period.

2.3 Measurement of Environmental Variables

On each sampling date, environmental variables such as transparency, temperature, pH, dissolved oxygen, Total Dissolved Solid (TDS) and conductivity were measured *in situ* between 08.00 am and 10.00 am. Water temperature, pH, total dissolved solid 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 (NH4 +), nitrite (NO2-), and phosphorus (PO43-) were carried out according to Grasshoff *et al*. (1983).

2.4 Statistical Analysis

In each sampling site, abundance, density, Shannon-Wiener diversity index (bits) (Shannon-Wiener, 1949), Pielou Evenness (Piélou, 1966) and Margalef index were calculated. Shannon-Wiener diversity index was used to quantify taxonomic richness and distribution of taxa in the communities. Evenness was used to determine aquatic insect distribution, regardless of species richness. The Margalef diversity index measure in a settlement (which is a homeostatic system) the total quantity of information resulting from the differentiation in species (Boudouresque, 1971). This index allows to better estimate the absolute richness, regardless of the sample size (Peet, 1974). In the present investigation, the Margalef diversity index was used to assess the ecological quality of the environment according to Lenat *et al.* (1980). Coefficient of similarity among sites was estimated following Sorensen (1948). Sorensen index was used to assess the similarity of insect communities between different sites. Analysis of variance (ANOVA) was used to determine effects of sites and seasons on environmental variables, Shannon-Wiener diversity, evenness, density and Margalef index. Before performing the comparison test, the normality of data was checked by Kolmogorov-Smirnov test. Data were $\log_{10}$ (X+1) transformed prior to analysis. Comparison of data collected at different stations was made using one-way ANOVA and Tukey's *post hoc* test. Relationships between the distribution of aquatic insects and environmental variables in all sampling sites were determined by Canonical Correspondence Analysis (CCA) using CANOCO 5.0 software. The importance of CCA was tested by the Monte Carlo test at *P-value*=0.024 (F- ratio=2.93) for 499 permutations. Taxa which represented at least 1% 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. Three environmental parameters were returned for the analysis.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Variables

The variations of environmental parameters are given in Table 1. The electric conductivity varied from 35.71 ± 2.62 µs.cm^{-1} (site B) to 41.15 ± 2.48 µs.cm-1 (site D). Water temperature ranged between 27.18 ± 0.66 °C (site A) and 29.00 ± 1.16 °C (site D). The lowest dissolved oxygen values were recorded in site C (4.11 ± 1.12 mg.L^{-1}) and the highest values were observed in site D (5.75 ± 0.72 mg.L^{-1}). Site C presented low values of pH (6.74 ± 0.19) while high values (6.92 ± 0.11) were recorded in site D. Water transparency fluctuated between

26.63 ±9.45 cm (site D) and 30.43 ± 5.55 cm (site A). TDS value was higher in site D (18.00 ± 1.04 mg.L^{-1}) and lower in site B (15.66 ± 1.43 mg.L^{-1}). Nitrite values varied between 0.61 ± 0.59 mg.L^{-1} (site A) and 1.14 ± 0.58 mg.L^{-1} (site D). Phosphorus oscillated between 1.82 ± 0.60 mg.L^{-1} (site A) and 2.23 ± 0.93 mg mg.L^{-1} (site C). Ammonium value varied from 0.17 ± 0.25 mg.L^{-1} (site D) to 0.37 ± 0.29 mg.L^{-1} (site A).

3.2 Taxonomic richness, abundance and density

A total of 10010 aquatic insects belonging to 62 taxa, 30 families and 8 orders (Ephemeroptera, Odonata, Heteroptera, Lepidoptera, Coleoptera, Trichoptera, Megaloptera and Diptera) were collected (Table 2). However, 69.35% of the total aquatic insect taxa richness was attributed to three taxonomic groups that included Heteroptera (16 taxa), Diptera (14 taxa) and Coleoptera (13 taxa). Chironomidae was the family who had the highest number of taxa (10 taxa). Table 3 summarizes variations of the number of taxa, abundance, density and diversity indexes among sites. Forty-seven taxa were recorded in site A, 31 taxa in site B, 34 taxa in site C and 46 taxa in site D. Twenty-six taxa were common to all the sites (Figure 2). The settlement in site A was composed by 14 Heteroptera, 12 Diptera, 9 Coleoptera, 5 Odonata, 4 Ephemeroptera, 2 trichoptera and 1 Lepidoptera. In site B, the settlement was constituated by 9 Heteroptera, 10 Diptera, 3 Coleoptera, 4 Odonata, 3 Ephemeroptera and 2 Trichoptera. In site C, aquatic insect population was constituated by 9 Heteroptera, 11 Diptera, 5 Coleoptera, 4 Odonata, 3 Ephemeroptera, 1 Megaloptera and 1 Trichoptera. In site D, the population was characterized by presence of 13 Heteroptera, 11 Diptera, 7 Coleoptera, 9 Odonata, 5 Ephemeroptera and 1 Lepidoptera. In water column, 6880 individuals were collected while in sediment, they were 3130. The highest and the lowest insect abundance were recorded at site B and site D respectively (Table 3). Heteroptera and Diptera recorded the highest abundance in all sites (Figure 3). Insect density in water column and in sediment showed significant fluctuations among sites ($F_{3, 48}$=45.30; *P*=0.000 and $F_{3,48}$=5.08; *P*=0.004 respectively). Density in water column was significantly higher in site A (454.60±129.19) compared to site B (129.07±35.12). The Heteropterans recorded the highest density in the four sites. *Plea pullula* was the most abundant taxa in site A with 36.19% of total density. *Plea pullula* (22.52%) and *Anisops sardea* (17.03%) were the most abundant in site B. In site C, these two taxa were the most important. They represented 22.70% and 17.71% of total density respectively. In site D, *Anisops sardea* (61.51%) and *Plea pullula* (17.12%) were the most abundant. In sediment, this parameter was significantly lower in site C (320.13±192.03) compared to site D (886.80±625.11). The Dipterans dominated quantitatively the sediment density in the four sites. Chironomidae was the most important family in term of abundance. *Stictochironomus* sp. was the most abundant in three sites. This taxon recorded 58.59%, 43.03% and 49.56% of density in site A, site B and site C respectively. In site D, *Tanypus fuscus* and *Nilodorum fractilobus* recorded the highest density. They represented 39.70% and 28.58% of benthic insect in this site. In the two facies (water column and sediment), seasonal variation of density didn't show significant difference among sites. Density was higher in the rainy season at the four sites in water column. In sediment, the highest density was obtained in the rainy season in site A and site C and in the dry season in site B and site D.

3.3 Diversity and Similarity Indexes

The spatial distribution patterns of Shannon-Wiener diversity showed significant difference among sites ($F_{3,48}$ =22.54; P=0.000). Evenness index also showed significant difference among sites ($F_{3,48}$ =49.43; P= 0.000). The highest values of Shannon-Wiener diversity and

Evenness indexes were recorded at site A (3.59±0.36) and site B (0.86±0.05) respectively (Table 3). Seasonal variation did'nt show significant difference in Shannon-Wiener diversity and Evenness indexes. Shannon-Wiener diversity was high during rainy season in Site A and during dry season in the others Sites, while the mean value of Evenness index was high during dry season in all sites. Margalef index showed significant difference among the sites ($_{F3,48}$=15.91; P=0.000). This index was higher in site A (3.23±0.51) and lower in site B (2.16±0.34). Seasonal variation did'nt show significant difference in Margalef diversity index. The mean value of this index was higher during dry season in Site A and Site B and lower in Site C and Site D.The Sorensen similarity index showed that site B and site C were strongly similar (QS=86.15) (Table 4). This index revealed that there was a minimum similarity between site C and D.

3.4 Relationships between Environmental Variables and Aquatic Insect Communities

The results of redundancy analysis revealed that the relationships between insect's taxa and their habitat conditions follow mainly the first two axes (Figure 4). These two axes accounted for 95.78% of the total variance. Water Transparency was positively correlated to axis I. High value of this variable was recorded at site A and C. Macrophyte was negatively correlated to axis II. Temperature was negatively correlated to axis II too. This parameter is higher in site D. The axis I opposed site C and B in positive coordinates to site A and D (in negative coordinates). Site A where macrophyte is very abundant was characterized by *Micronecta* sp., *Diplonychus* sp., *Ranatra parvipes*, *Eurymetra* sp., *Stictochironomus* sp., *Cloeon gambiae*, *Mesovelia* sp., *Plea pullula*, *Amphiops* sp. and *Cloeon bellum*. These taxa were associated with abundant macrophyte. Site D which contain also important macrophyte and where temperature is high was characterized by presence of *Nilodorum fractilobus*, *Anisops sardea*, *Limnogonus chopardi*, *Tanypus fuscus*, *Chaoborus anomalus* and *Chironomus imicola*. These taxa prefered habitat with macrophyte and high temperature. Site C where water transparency was higher was characterized by presence of *Polypedilum* sp.

4-DISCUSSION

Eight orders of aquatic insects were collected in this investigation. These orders were Ephemeroptera, Odonata, Heteroptera, Lepidoptera, Coleoptera, Trichoptera, Megaloptera and Diptera. Globally, the composition of the settlement corresponds to that generally encountered in ponds. This result is in appropriateness with these obtained by Jana *et al*. (2009), by Yapo *et al*. (2013, 2015), by Edia (2013) and by Dalai and Gupta (2014). Orders Heteroptera, Diptera and Coleoptera recorded the most of aquatic insect taxa richness. They represented 69.35% of the total taxa collected. The dominance of Diptera and Heteroptera in term of richness was noted by Edia (2013) in some ponds of the northern Côte D'Ivoire. Similar study reported Diptera and Heteroptera as the best-represented insect orders (Fischer *et al.*, 2000; Boix *et al.*, 2001). Considering these two orders, maximum richness tends to concentrate in a few families, namely: Corixidae, Gerridae and Notonectidae among Heteropterans and Chrironomidae among Dipterans. Families Corixidae among Heteropterans and Chironomidae among Dipterans were pointed out as the best represented families among these two orders (Edia, 2013). In order Coleoptera, the maximum richness was recorded by four families (Dytiscidae, Elmidae, Hydrophilidae and Curculionidae). The preponderance of Dytiscidae and Hydrophilidae among Coleopterans was indicated by Jana *et al*. (2009). Such preponderance of Dytiscidae over Hydrophilidae indicates the ecological condition of aquatic body. Dytiscidae family generally inhabits leaf of bottom macrophytes of the clean freshwater

and are predacious in nature. Hydrophilidae family on the contrary, are water scanvenger beetles and generally occur in shallower regions of the wetland with abundant macrophytes particularly emergent ones and feed mainly on detritus, algae and decaying vegetative matter (Khan and Ghosh, 2001). Odonata was the fourth order in term of species richness after Heteroptera, Diptera and Coleoptera. The settlement representatives of order Odonata were collected at all sites. According to Kalkman *et al*. (2008), Odonata are widespread and centers of species richness typically occur in tropical forests. This order was represented by two families namely Coenagrionidae and Libellulidae. Our investigation showed that family Coenagrionidae was the most richness family among order Odonata but many studies revealed that family Libellulidae is widely represented in surveys locally and globally (Newbury, 1984; Che Salmah and Wahizatul, 2004). Previous study on the Takmu area of the Loktak Lake, Manipur also revealed the highest number of species from the family Libellulidae (Takhelmayum and Gupta, 2011). In total, 10010 individuals of aquatic insects were collected. Abundance fluctuated from a site to other. It varied from 1223 individuals (Site B) to 3843 individuals (Site D). The second site in term of abundance is Site A. This spatial variation could be attributed to the diverse influences subjected by the environment and also to the nature of the different habitats. We mentioned that Site A and D contained important macrophytes. Site C contained less important macrophytes and Site B didn't contain macrophytes. The presence or absence of macrophytes in these sites could be explained the difference in abundance observed between them. Heteroptera and Diptera recorded the highest abundance in all sites. In Site A, *Plea pullula* among Heteroptera and *Stictochironomus* sp. among Diptera were the most abundant. In Site B and Site C, *Anisops sardea* and *Plea pullula* among Heteroptera and *Stictochironomus* sp. among Diptera were the most important while *Anisops sardea* and *Plea pullula* among Heteroptera and *Nilodorum fractilobus* and *Tanypus fuscus* among Diptera recorded the highest abundance in Site D. Abundance of Heteroptera and Diptera was observed in previous studies (Della Bella *et al.* 2005; Apinda-Legnouo, 2007; Edia, 2013; Ben Moussa *et al*., 2014 ; Takhelmayum and Gupta, 2015, Yapo *et al*., 2013; Yapo *et al*., 2015). Notonectidae, Pleidae (Heteroptera) and Chironomidae (Diptera) were numerically the most dominant families. The predominance of Chironomidae was illustrated by Dejoux *et al*. (1968) in Lac Tchad. *Anisops sardea*, *Plea pullula* and *Stictochironomus* sp. were reported to be the most abundant taxa (Edia, 2013; Yapo *et al*., 2013; Yapo *et al*., 2015). The predominance of Diptera in term of abundance or density was due to those of representatives of family Chironomidae. Leonard and Ferrington (2007) mentioned that Chironomidae are big consumers of algae. The high densities of Chironomidae at the different sites let us suppose that these sites are characterized by an important development of algae. According to Ouattara *et al.* (2001), stagnant waters promote algae reproduction and development so that the Chironomidae of fourth sites found enough algae to fulfil their foodneed. Diversity index can be used to measure environmental stress (Mason, 1981). Iwasaki (1999) opined that environmental stability rather than spatial heterogeneity has greater influence on H. In the present study Shannon diversity index values showed fluctuations among the sites and they were higher than 2.60 in all the sites indicating undisturbed nature of the ecosystems. High species diversity is an indication of fine distribution of resources among individuals of many species of a community (Mason, 1990). Evenness values of the sites ranged from 0.61 to 0.86. They were closer to 1 indicated equal distribution of individuals (Turkmen and Kazanci, 2010). The values of Margalef diversity index were between 2.16 and 3.23. According to Lenat *et al.* (1980), Margalef water quality index values (diversity index of Margalef) greater than 3 indicate clean conditions, values less than 1 indicate severe pollution and intermediate value indicate moderate pollution. In the

present investigation, only in site A the Margalef Diversity Index value was found above 3 indicating clean condition whereas all other sites were found in the range of moderate pollution. Also the presence of insect orders Ephemeroptera and Trichoptera which are included in the EPT (Ephemeroptera, Plecoptera and Trichoptera) i.e. sensitive group of insects, is an indication of good water quality (Rosenberg & Resh 1993). In this study, the pattern distribution according to environmental variables indicates that *Nilodorum fractilobus*, *Anisops sardea*, *Limnogonus chopardi*, *Tanypus fuscus*, *Chaoborus anomalus* and *Chironomus imicola* were associated to high value of temperature. A similar result was observed by Diomandé *et al*. (2009) in Bia River (southern Côte d'Ivoire), by Yapo *et al*. (2013) in some fish farm ponds of southern Côte d'Ivoire and by Ogbeibu (2001) who observed a significant positive correlation between density and water temperature in temporary pond in Okomu Forest Reserve. According to Ross *et al*. (1982), temperature is one of the most important environmental factors controlling aquatic insect density. Canonical analysis showed association with aquatic insect and macrophytes. The importance of macrophyte habitats on macroinvertebrates taxonomic diversity was shown by Kouamé *et al*. (2010) and Kouamé *et al*. (2011) in Taabo lac (Côte d'Ivoire). Indeed, these habitats are used by the macroinvertebrates as food resource, shelter against predators and for reproduction (Murphy and Giller, 2000; Jesus, 2006).

CONCLUSION

This study allowed us to identify 62 taxa of aquatic insect in an artificial non-stocked pond. The settlement was dominated by Hetroptera, Diptera and Coleoptera. The maximum richness was observed in Site A and Site D where macrophytes is abundant. This study revealed that water quality of the pond is good as supported by the values of biological indices and by presence of insect of orders Ephemeroptera and Trichoptera.

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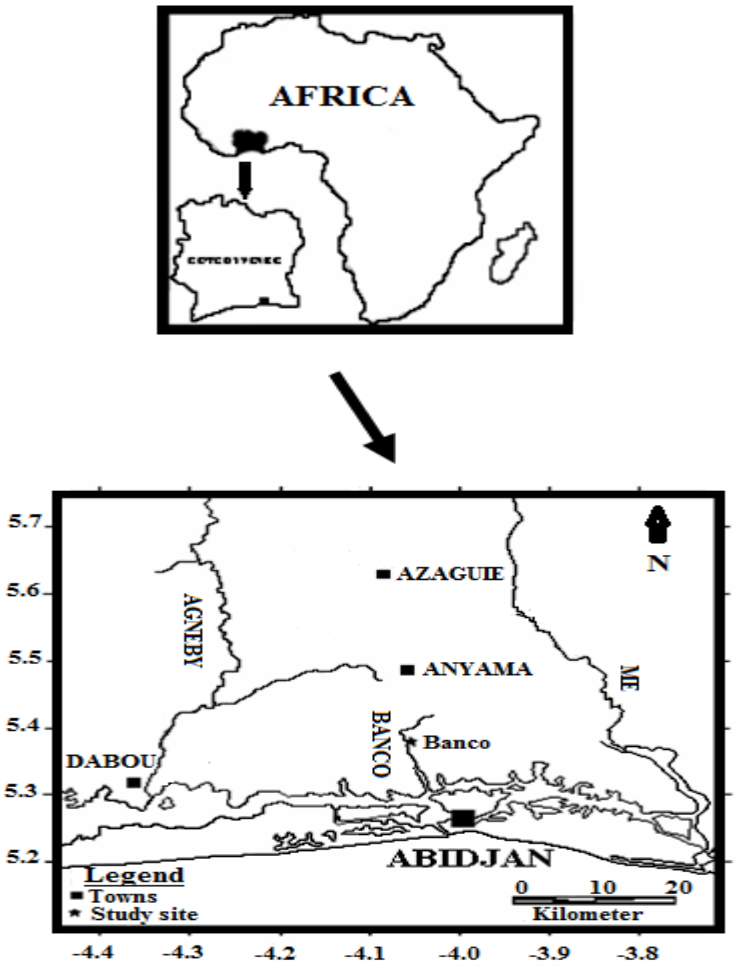


Figure 1: Location of the study site.

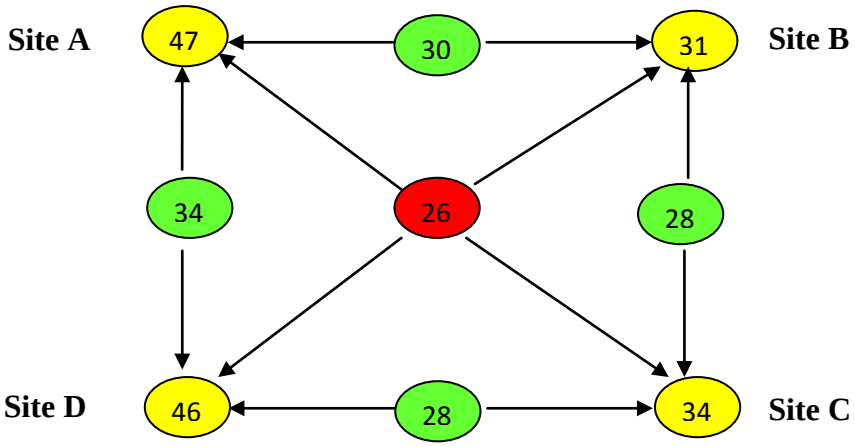
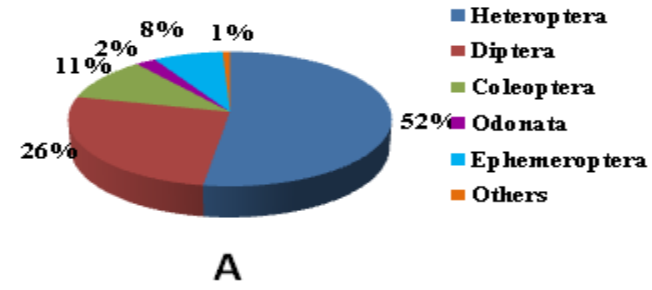


Figure 2: Taxonomic composition similarity between different sites.

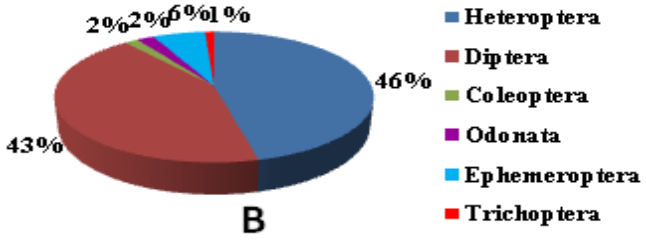
Number of taxa specific to a site

Number of taxa common to two sites

Number of taxa common to four sites



A



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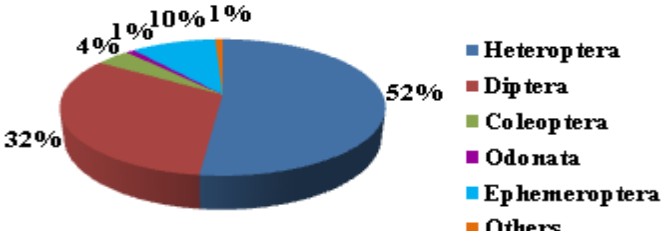

C

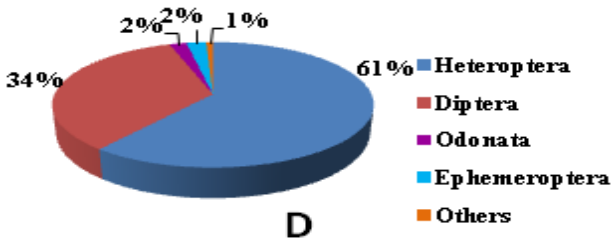

Figure 3: Relative abundance of aquatic insect orders in the different sites.

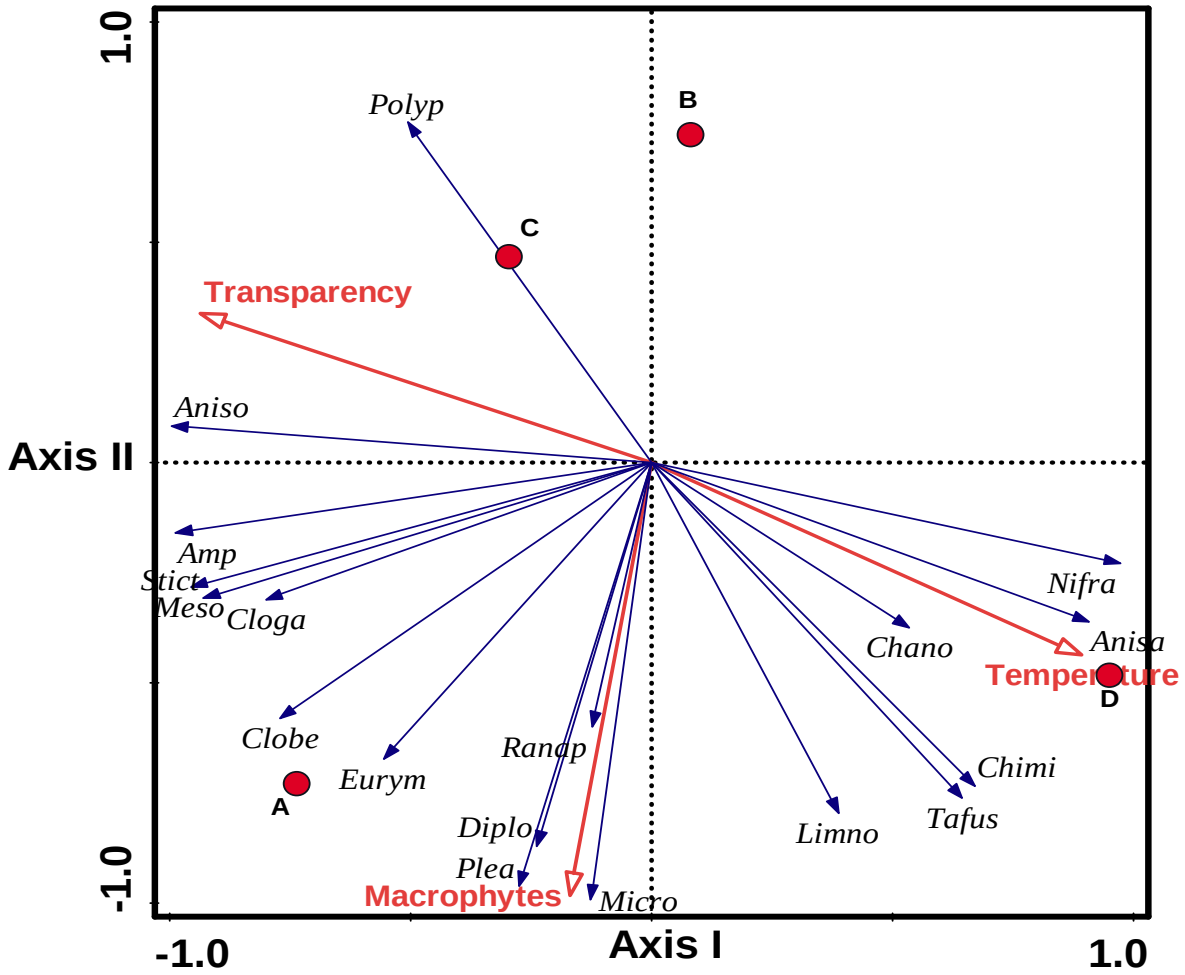

Figure 4. Canonical correspondence analysis carried out with selected environmental Variables and with the dominant insect taxa. Taxa codes

Amp: *Amphiops* sp.; ***Anisa***: *Anisops sardea*; ***Aniso***: *Anisops* sp.; ***Chano***: *Chaoborus anomalus*; ***Chimi***: *Chironomus imicola*; ***Clobe***: *Cloeon bellum*; ***Cloga***: *Cloeon gambiae*; ***Diplo***: *Diplonychus* sp.; ***Eurym*:** *Eurymetra* sp.; ***Limno***: *Limnogonus chopardi*; ***Meso***: *Mesovelia* sp.; ***Micro***: *Micronecta* sp.; ***Nifra***: *Nilodorum fractilobus*; ***Plea***: *Plea pullula*; ***Polyp***: *Polypedilum* sp.; ***Ranap***: *Ranatra parvipes* ; ***Stict***: *Stictochironomus* sp.; ***Tafus***: *Tanypus fuscus*.

Table 1. Physicochemical characteristics (mean ± (SD)) of water at various sampling sites.

Variables	Sites			
	A	B	C	D
Secchi disk transparency (cm)	30.43±5.55[a]	29.90±4.59[a]	30.10±2.38[a]	26.63±9.45[a]
Temperature (°C)	27.18±0.66[a]	27.21±0.58[a]	27.20±0.61[a]	29.00±1.16[b]
Conductivity (µS.cm^{-1})	35.93±2.74[a]	35.71±2.62[a]	35.90±3.45[a]	41.15±2.48[b]
Dissolved oxygen (mg.L^{-1})	4.14±1.15[a]	4.30±1.28[a]	4.11±1.12[a]	5.75±0.72[b]
pH	6.75±0.23[a]	6.77±0.17[a]	6.74±0.19[a]	6.92±0.11[a]
Total Dissolved Solid (mg.L^{-1})	16.33±1.61[a]	15.66±1.43[a]	15.91±1.83[a]	18.00±1.04[b]
Nitrite (mg.L^{-1})	0.61±0.59[a]	1.08±0.87[a]	1.09±0.91[a]	1.14±0.58[a]
Ammonium (mg.L^{-1})	0.37±0.29[a]	0.24±0.30[a]	0.25±0.33[a]	0.17±0.25[a]
Phosphate (mg.L^{-1})	1.82±0.60[a]	2.18±1.00[a]	2.23±0.93[a]	2.00±1.12[a]

[a, b]: letters showed the difference between the sites as regards the parameter indicated

Table 2. List of taxa collected from the sites. 1=presence of the taxon; 0=absence

Order	Families	Taxa	Site A	Site B	Site C	Site D
Ephemeroptera	**Caenidae**	*Caenis* sp.	0	0	0	1
	Baetidae	*Cloeon bellum*	1	1	1	1
		Cloeon gambiae	1	1	1	1
		Cloeon smaeleni	1	1	1	1
	Polymitarcyidae	*Povilla adusta*	1	0	0	1
Odonata	**Coenagrionidae**	*Ceriagrion* sp.	1	1	1	1
		Ischnura sp.	0	0	0	1
		Coenagrionidae	0	0	0	1
		Pseudagrion wellani	1	1	1	1
		Pseudagrion sp.	1	0	1	1
	Libellulidae	*Libellula* sp.	1	1	1	1
		Orthetrum sp.	0	0	0	1
		Brachythemis sp.	1	1	0	1
		Pantala flavescens	0	0	0	1
Heteroptera	**Belostomatidae**	*Diplonychus* sp.	1	1	1	1
	Gerridae	*Eurymetra* sp.	1	1	1	1
		Limnogonus chopardi	1	1	1	1
		Naboandelus sp.	0	0	0	1
	Corixidae	*Micronecta* sp.	1	1	1	1
		Stenocorisea protrusa	1	0	0	1
		Sigara sp.	0	0	0	1
	Notonectidae	*Anisops sardea*	1	1	1	1
		Anisops sp.	1	1	1	1
		Enithares sp.	1	0	0	0
	Pleidae	*Plea pullula*	1	1	1	1
	Naucoridae	*Naucoris* sp.	1	0	0	0
		Macrocoris flavicolis	1	0	0	0
	Veliidae	*Rhagovelia reitteri*	1	0	0	1
	Mesoveliidae	*Mesovelia* sp.	1	1	1	1
	Nepidae	*Ranatra parvipes*	1	1	1	1
Megaloptera	**Corydalidae**	Corydalidae	0	0	1	0
Lepidoptera	**Crambidae**	Crambidae	1	0	0	1
Coleoptera	**Hydrophilidae**	*Amphiops* sp.	1	1	1	1

		Hydrochara rickseckeri	1	1	1	1
	Dytiscidae	*Canthydrus xanthinus*	1	0	1	1
		Hyphydrus sp.	1	0	1	0
		Cybister tripunctatus	0	0	0	1
		Laccophilus vermiculosis	0	0	0	1
	Elmidae	*Limnius* sp.	1	0	0	0
		Esolus sp.	1	0	0	0
		Potamodytes sp.	0	0	0	1
	Curculionidae	*Pseudobagous* sp.	1	0	0	0
		Bagous glabrirostris	1	0	0	0
	Chrysomelidae	*Macroplea* sp.	1	1	1	0
	Spercheidae	*Spercheus ceryisi*	0	0	0	1
Trichoptera	**Polycentropodidae**	*Dipseudopsis capensis*	1	1	1	0
	Hydropsychidae	*Protomacronema* sp.	0	1	0	0
	Hydroptilidae	*Hydroptila* sp.	1	0	0	0

Table 2. Extented

Order	Families	Taxa	Site A	Site B	Site C	Site D
Diptera	**Chironomidae**	*Tanypus fuscus*	1	1	1	1
		Nilodorum fractilobus	1	1	1	1
		Nilodorum brevipalpis	1	1	1	1
		Polypedilum sp.	1	1	1	1
		Chironomus imicola	1	1	1	1
		Stictochironomus sp.	1	1	1	1
		Clinotanypus claripennis	1	1	1	1
		Ablabesmyia dusoleili	1	0	1	0
		Cryptochironomus sp.	1	0	0	1
		Stenochironomus sp.	0	0	1	0
	Ceratopogonidae	*Ceratopogon* sp.	0	0	0	1
	Tabanidae	*Tabanus* sp.	1	1	0	0
	Culicidae	*Culex quinquefasciatus*	1	1	1	1
	Chaoboridae	*Chaoborus anomalus*	1	1	1	1
Total=8	**30**	**62**	**47**	**31**	**34**	**46**

Table 3. Spatial variation of number of taxa, abundance, density, Shannon-Wiener diversity index (bits), and evenness among sites (mean ± (SD))

Parameters	Site A	Site B	Site C	Site D
Number of taxa	47	31	34	46
Abundance	3460	1223	1484	3843
Density in water column (ind.m^{-2})	454.60±129.19^{c}	129.07±35.12^{a}	181.20±43.56^{b}	451.41±109.51^{c}
Density in sediment (ind.m^{-2})	622.22±457.35^{ab}	343.75±189.36^{a}	320.13±192.03^{a}	886.80±625.11^{b}
Shannon-Wiener index	3.59±0.36^{b}	3.37±0.25^{b}	3.34±0.33^{b}	2.66±0.19^{a}
Evenness	0.76±0.06^{b}	0.86±0.05^{c}	0.83±0.04^{c}	0.62±0.04^{a}
Margalef index	3.23±0.51^{b}	2.16±0.34^{a}	2.24±0.44^{a}	2.33±0.42^{a}

$^{a, b, c}$ letters in the same row show differences among sites (P=0.05).

Table 4. Sorensen similarity index of aquatic insect's communities recorded in the different sites.

Sites	A	B	C	D
A		76.92	79.01	73.11
B	76.92		**86.15**	70.12
C	79.01	**86.15**		70.00
D	73.11	70.12	70.00	