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Spatial variation of aquatic insect community in fish farms pond in the Southern Côte d'ivoire, West Africa

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Abstract

Species composition and community structure of aquatic insects carried out from December 2007 to November 2008 in five fish farm ponds in Southern Côte d'Ivoire (Layo, Banco, Azaguié, Anyama I and Anyama II). Samples were collected monthly in water column and sediment using a 350 µm mesh hand net and a Van veen grab respectively. Each habitat was collected in six replicates. A total of 79 taxa belonging to 35 families and 8 orders were identified. Eight of them (*Cloeon bellum*, *Cloeon gambiae*, *Cloeon smaeleni*, *Valleriola* sp., Corydalidae, *Bagous* sp., *Pseudobagous* sp. and *Macroplea* sp) were reported for the first time in Côte d'Ivoire aquatic ecosytems. Significant assemblage differences between insect communities from freshwater and brackish water were observed. However, the common dominant species for freshwater and brackish water were *Anisops sardea*, *Eurymetra* sp., *Limnogonus chopardi, Mesovelia* sp., *Ranatra parvipes*, *Nilodorum fractilobus*, *Tanypus fuscus, Chironomus imicola*, *Ceratopogon* sp., *Chaoborus anomalus*, *Stictochironomus* sp., *Cloeon bellum* and *Cloeon gambiae*. The station of Banco recorded the highest species diversity (H'), evenness (J), species richness (d) and dominance (λ) indices of aquatic insects. The five stations were clustered into three groups with similar species composition at 75% similarity. According ANOSIM routine, seventeen species are responsible for the dissimilarity between the groups defined. *Anisops sardea* represents the largest share of this dissimilarity.

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Introduction

Insects represent more than 70% of known specific biodiversity of the animal kingdom (Bameul, 2008). Besides their size, the interest of insects is their remarkable diversity of forms and adaptations that allowed them to colonize all habitats (Bameul, 2008). The role of insects in nature is well documented. Their importance as an indicator of environmental quality (Arimoro & Ikomi, 2009; Arimoro & Muller, 2009; Varandas & Cortes, 2010) and as a food source for many invertebrates and many fish species has been recognized (Kouamelan *et al.,* 2000; Diétoa *et al.*, 2007; Konan *et al.*, 2008). Particularly, in Côte d'Ivoire, substantial literatures on aquatic insects are available (Dejoux *et al.,* 1981; Yapo *et al.,* 2007, 2012, 2013; Edia *et al.*, 2007, 2010; Edia, 2013; Kouadio *et al.,* 2008; Diomandé *et al.,* 2009, Kouamé *et al.,* 2011). Only a few studies have been devoted to aquatic insects in fish farm ponds (Yapo *et al.*, 2007, 2012, 2013; Edia, 2013). Although there have been few study involved in the aquatic insects community structure. The aquatic insect in the fish farms ponds have little been studied. As part of a comprehensive investigation of ecosystem dynamics in artificial ponds, a study has been made of aquatic insects. This paper deals with the species composition and community structure, of aquatic insects in the fish farms ponds. It will (1) assess the similarity of the insect community between the different stations, (2) and show the species responsible for differences between the stations supplied with fresh water and brackish water

Materials and methods

Study site

This study was undertaken in five fish farms in the southern region of Côte d'Ivoire characterized by four seasons (two dry and two rainy seasons). The dry seasons extend from December to March and from August to September while the rainy ones extend from April to July and from October to November. Sampling sites were assigned to habitat types according to environmental and ecological features: 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) (Fig. 1). Banco site is located in National Park of Banco which surrounding ecosystem comprised of primary forest. In Azaguié, Anyama I and Anyama II, surrounding ecosystems comprised of agricultural landscape and at Layo site, immediate environment was characterized by habitation. 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 this last site were fed by brackish water (salinity ranging from 0 to 10 $mg.L^{-1}$ (Legendre *et al.*, 1987) while in the four others sites, ponds were supplied with fresh water. All ponds at all sites were permanent and were shallow (depth < 1 m). In each site, three ponds were randomly selected for this study. Pond area varied from 280 m^2 to 500 m^2. Bottom sediment are mostly composed by sand in Layo and Azaguié stations, by mud in Banco, sand and clay in Anyama I while in Anyama II station, mud and sand were the dominant substrat. Tilapia *Oreochromis niloticus* Linnaeus, 1758 is the only fish species breeded in the different fish farm ponds except Banco where pond were abandoned. In each site, pond were originally man-made. The rice bran was the food provided to the fish. Feeding frequency was 3 sessions per day. Density of loading is from 3 to 5 fish/m^2 (Layo), 6 fish/m^2 (Azaguié and Anyama II) and 7 fish/m^2 (Anyama I).

Aquatic insect and environmental variable collection

In each pond, samples were collected monthly from December 2007 to November 2008. Each farm environmental variables and insects were respectively measured and sampled on the same day. One farm is sampled per day. Water column and sediment were sampling using a 350 µm mesh hand net and a Van veen grab (area = 0.09 m^2) respectively. Each habitat was sampled in six replicates. The water column and sediment samples collected were respectively sieved through 300 µm and 1 mm aperture size sieve. The materials retained were preserved *in situ* in 10%

formalin. In the laboratory, specimens were sorted and identified to the lowest possible taxonomic level (species, genus, family) by means of the keys in Dejoux *et al.* (1981); Tachet *et al.* (2003), de Moor *et al.* (2003 a), de Moor *et al.* (2003 b) and Gattoliat (com. pers.). On each sampling date, environmental variables such as transparency, temperature, pH, dissolved oxygen and conductivity were measured *in situ* between 08.00 and 10.00 a.m. 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 phosphate, PO_4^{3-}) from filtered samples were carried out according to Grasshoff *et al.* (1983).

Data analyses

The species diversity, dominance, evenness and species richness index of each station were calculated respectively using the Shannon-Wiener (1963) index (H'), Simpson index (λ), Pielou (1966) index (J) and Margalef (1958) richness index (d). Analysis of variance (ANOVA) was used to assess the spatial and seasonal effects on environmental variables, Shannon-Wiener diversity, evenness, density and biomass. Before performing the comparison test, the normality of data was checked by the Kolmogorov-Smirnov test. Data were $\log_{10}(X+1)$ 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. Analyses were conducting using Statistica 7.1 software. The PRIMER 5.0 software (Plymouth Marine Laboratory; Clarke & Gorley 2001) was used to calculate Bray-Curtis (dis)similarities between all samples. Samples were grouped together concordantly with a spatial scale: the different sampling locations (Layo/Banco/Azaguié/Anyama I / Anyama II). The obtained similarity matrix was used to produce non-metric Multidimensional Scaling two-dimensional plots (nMDS). The stress value gives a measure for goodness-of-Wt of the nMDS ordination: a low-stress value (< 0.2) indicates a good ordination with no real prospect for a misleading interpretation (Clarke 1993). One-way Analysis of Similarities (ANOSIM) was carried out to test for significant differences in the aquatic insect community structure between water natures in fish farm ponds stations. For that the stations are grouped to freshwater stations and brackish station. Similarity Percentages (SIMPER) was used to investigate which taxa were responsible for these differences. K-dominance curves were plotted for the comparison of species composition at the stations using Primer 5.0. Moreover, relationships between the distribution and abundance of aquatic insects and environmental variables for all the five sampling stations were determined by Canonical Correspondence Analysis (CCA) using CANOCO 4.5 software (ter Braak & Smilauer, 2002). Taxa which were responsible for the difference between brackish water and freshwater environment were included in this analysis. The significance of the Canonical Correspondence Analysis (CCA) was tested by the Monte Carlo test that evaluates the significance and stability of decomposition of the total inertia of the cross-table with only permutation table rows environmental parameters (Kazi-aoual *et al.*, 1995). This test showed a significance of the inertia projected at 5% for 499 permutations.

Results

Physical and chemical variables

A summary of the environmental variables collected at the study stations is given in Table 1. The mean value of electrical conductivity was high in Layo (3037.83 ± 2980.25 µS / cm) and low in Banco (35.85 ± 2.88 µS / cm). Dissolved oxygen was low in Banco (4.18 ± 1.15 mg.L^{-1}) and high in Anyama I (6.33 ± 0.44 mg. L^{-1}). The highest value of temperature (28.97 ± 1.10°C) was in Azaguié while the lowest value (27.20 ± 0.60 °C) was recorded in Banco. The maximum transparency level (30.14 ± 4.25 cm) was recorded in Banco while the lowest (21.65 ± 6.84 cm) was recorded in Layo. The pH value (7.08 ± 0.12) was maximal in Anyama I and minimal in Banco (6.75 ± 0.19). Nitrite values varied between 0.62 ± 0.52 mg.L^{-1} (Anyama I) and 1.26 ± 0.84 mg.L^{-1} (Layo). Phosphate 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.

Table 1. Physicochemical characteristics of water at various sampling stations.

Parameters	Stations				
	Layo	Banco	Azaguié	Anyama I	Anyama II
Secchi disk transparency (cm)	21.65±6.84^{a}	30.14±4.26^{b}	22.05±7.65^{a}	21.99±5.03^{a}	23.05±4.73^{a}
Temperature (°C)	28.36±1.11^{b}	27.20±0.60^{a}	28.97±1.10^{b}	28.80±1.07^{b}	28.80±0.88^{b}
Dissolved oxygen (mg.L^{-1})	5.55±1.32^{b}	4.18±1.15^{a}	5.71±0.66^{bc}	6.33±0.44^{d}	6.16±0.40^{cd}
pH	6.93±0.11^{b}	6.75±0.19^{a}	6.90±0.11^{b}	7.08±0.12^{c}	7.04±0.16^{c}
Conductivity (µs.cm^{-1})	3037.83±2980.25^{b}	35.85±2.88^{a}	38.05±4.08^{a}	71.22±14.10^{a}	49.14±16.67^{a}
Nitrite (mg.L^{-1})	1.26±0.84^{b}	0.93±0.81^{ab}	1.02±0.55^{ab}	0.62±0.57^{a}	1.06±0.44^{b}
Ammonium (mg.L^{-1})	0.23±0.30^{ab}	0.31±0.36^{b}	0.17±0.26^{ab}	0.16±0.20^{ab}	0.12±0.16^{a}
Phosphate (mg.L^{-1})	2.47±1.44^{b}	2.08±0.86^{b}	2.05±1.21^{b}	1.09±0.69^{a}	2.10±0.79^{b}

Table 2. List of taxa and mean abundance collected from 3 fish ponds at each station.

Taxa	Stations					Mean abundance per order
	Layo	Banco	Azaguié	Anyama I	Anyama II	
Ephemeroptera						508.33
Cloeon bellum, Navas	101.00	78.33	35.00	39.00	34.00	
Cloeon gambiae, Gillies	26.66	59.00	20.33	14.33	16.00	
Cloeon smaeleni, Lestage	15.33	24.00	4.66	10.00	5.66	
Povilla adusta, Navas		3.66	0.33	0.33	1.33	
Caenis sp., Stephens			1.33	13.33	4.66	
Odonata						201
Coenagrionidae, Kirby			0.66		2.00	
Ceriagrion sp.	5.00	10.66	4.33	2.33		
Pseudagrion wellani	15.00	13.33	16.00	21.33	15.33	
Pseudagrion sp. Selys	3.66	6.66	9.66	6.00	8.66	
Ischnura sp. Selys	6.33		0.33			
Libellula sp., Karsch		2.66	0.66	1.00	3.00	
Orthetrum sp., Calvet			0.33	1.66		
Crocothemis sp., Friedrich	0.33					
Brachythemis sp.	10.66	6.00	10.33	8.00	5.33	
Pantala fabricius, Fabricius			1.00			
Ictinogomphus sp., Frazer				2.66		
Hemiptera						7882.67
Appasus sp. Amyot & Serville	34.00	28.66	2.66		0.66	
Diplonychus sp., Laporte	53.00	12.66	21.66	2.66	12.66	
Eurymetra sp.	22.66	96.00	50.33	113.00	71.66	
Limnogonus chopardi, Stal	25.66	23.66	25.00	36.33	44.00	
Naoboandelus sp., Distant	0.33		0.33	0.33	0.33	
Micronecta sp., Kirkaldy	15.00	43.66	31.66	14.00	5.66	
Sigara sp., Fabricius			1.00			
Stenocorisea protrusa Horv	6.00	1.00	3.33		1.66	
Notonectidae, Leach	4.00	45.33	7.00	11.66	7.00	
Anisops sardea,, Poisson	1031.00	151.00	1752.00	1358.00	1565.33	
Anisops sp. Spinola	6.66	31.00	5.00	6.00	14.66	
Enithares sp. Spinola	3.33	0.66		2.66	0.33	
Naucoris sp. Geoffroy	4.33	0.66				
Macrocolis flavicolis, Signoret		6.66		1.00		
Plea pullula, Stal	87.66	441.33	7.00			
Rhagovelia reitteri, Poisson		1.00	0.33	1.33		
Mesovelia sp., Douglas& Scott	132.66	125.00	15.66	61.33	11.33	
Hydrometra sp., Latreille				0.33		
Laccotrephes ater, Linné				0.33	1.00	
Ranatra parvipes, Fabricius	41.66	41.00	29.33	42.00	25.33	
Valleriola sp., Costa				0.33		
Megaloptera						0.33
Corydalidae		0.33				
Lepidoptera						10
Pyralidae, Latreille	9.34	0.33			0.33	

Table 2. Extented.

Taxa	Stations					Mean abundance per order
	Layo	Banco	Azaguié	Anyama I	Anyama II	
Coleoptera						482.33
Amphiops sp., Erichson	88.66	109.66	1.00	0.00	2.66	
*Hydrochara ricksecker*i. Horn	5.00	8.66	5.00	5.00	2.00	
Hydrobius sp., Curtis	1.66	0.00	0.00	0.00	0.00	
Canthydrus minutus, Regimbart	113.66	0.00	0.00	0.00	0.00	
Canthydrus xanthinus, Regimbart	30.33	5.66	6.33	1.33	5.33	
Cybister tripunctatus, Olivier	5.00	0.00	0.66	0.00	0.00	
Hydrocanthus micans, Wehncke	7.33	0.00	0.00	0.00	0.00	
Hydrocoptus simplex, Guignot	0.33	0.00	0.00	0.00	0.00	
Laccophilus vermiculosus, Leach	0.00	0.00	1.00	0.00	0.33	
Yola tuberculata, Régimbart	0.33	0.00	0.00	0.00	0.00	
Hyphydrus sp., Montrouzier	0.00	0.66	0.00	0.00	0.00	
Limnius sp.,	13.00	4.00	0.00	0.33	0.33	
Esolus sp., Kuwert	0.00	1.33	0.00	0.33	0.00	
Potamodytes sp., Grandidier	0.00	0.00	0.33	0.00	0.66	
Potamophilus sp., Dufour	0.33	0.00	0.00	0.00	0.00	
Pseudobagous sp.	3.00	2.00	0.33	0.00	1.00	
Bagous sp., Germar	2.66	1.00	0.00	0.33	0.00	
Orectogyrus sp., Regimbart	0.00	0.00	0.00	4.33	23.33	
Aulonogyrus sp., Regimbart	0.00	0.00	0.00	0.00	0.33	
Macroplea sp., Curtis	0.00	15.00	0.00	0.00	0.00	
Sperchus ceriyisi, Guerin	0.00	0.00	0.66	0.00	0.00	
Trichoptera						20.33
Dipseudopsis capensis, Walker	0.00	16.33	0.00	0.00	1.33	
Protomacronema sp., *Hen1ng*	0.00	0.66	0.00	0.00	0.00	
Hydroptila sp., Gautier	0.00	0.33	0.00	0.00	0.00	
Ecnomus sp., McLachlan	0.00	0.00	0.00	1.66	0.00	
Diptera						2757.67
Tanypus fuscus, Freeman	1.66	110.66	366.66	154.00	195.33	
Nilodorum fractilobus, Kieffer	41.33	31.66	231.00	11.33	46.66	
Nilodorum brevipalpis, Kieffer	0.00	13.66	14.33	3.66	7.33	
Polypedilum sp., Kieffer	1.33	29.33	8.66	4.00	2.00	
Chironomus imicola, Kieffer	44.00	30.33	69.66	43.00	103.00	
Stictochironomus sp., Kieffer	0.00	329.33	96.33	188.66	104.66	
Clinotanypus claripennis, Kieffer	0.00	24.33	14.00	12.33	17.00	
Ablabesmyia dusoleili, Goetghebuer	0.00	3.00	0.00	0.00	5.66	
Cryptochironomus sp., Kieffer	0.00	1.66	22.33	0.00	0.00	
Cricotopus kisantuensis, Goetghebuer	0.00	0.00	0.00	0.00	2.66	
Stenochironomus sp., Kieffer	0.00	1.00	0.00	0.33	0.00	
Tabanus sp., Linné	0.00	3.00	0.00	0.00	0.66	
Chaoborus anomalus, Edwards	0.00	48.00	66.00	37.00	44.33	
Ceratopogon sp., Meigen	1.00	0.00	17.33	15.33	112.66	
Culex quinquefasciatus, Linné	12.66	10.00	1.00	0.66	0.00	
Total=79	2034,66	2055,66	2980,00	2255,00	2537,33	11862.66

Species composition and diversity

A total of 79 taxa, belonging to 35 families and 8 orders were recorded. Eight among them (i. e. *Cloeon bellum*, *Cloeon gambiae*, *Cloeon smaeleni*, *Valleriola* sp., Corydalidae, *Bagous* sp., *Pseudobagous* sp. and *Macroplea* sp.) were recorded for the first time in Côte d'Ivoire. The aquatic insect communities in Banco station, with 53 taxa, were the most diversified. the low taxa richness (44 taxa) was registered in Layo station. The list of all recorded taxa is provided in Table 2. The common dominant species at least in four stations were *Anisops sardea*, *Eurymetra* sp., *Tanypus fuscus, Chironomus imicola*, *Chaoborus anomalus*, *Stictochironomus* sp. and *Cloeon bellum.* The cluster of stations based on Bray-Curtis similarity after square root transformation of mean abundance of aquatic insects for each station in relation to other stations linked the stations in three major groups at 75% similarity (Fig.2). Groups I and II were composed respectively by Layo and Banco. The last group includes the other three stations namely Azaguié, Anyama I and Anyama II. The non-metric

Multidimensional Scaling ordination plot was represented by Fig.3. The similarity percentage (SIMPER) was used to show the species responsible for differences between Layo (brackish water) and the other (freshwater). The responsible taxa for these differences were shown in Table 3. *Cloen bellum*, *Cloeon gambiae Cloeon smaeleni* (Ephemeroptera), *Brachythemis* sp. *Pseudagrion wellani*, *Pseudagrion* sp. (Odonata), *Ranatra parvipes*, *Limnogonus chopardi*, *Anisops sardea*, *Anisops* sp., *Diplonychus* sp., *Eurymetra* sp., *Micronecta* sp., *Mesovelia* sp., Notonectidae (Heteroptera), *Hydrochara rickseckeri*, *Canthydrus xanthinus* (Coleoptera), and *Chironomus imicola*, *Nilodorum fractilobus*, *Polypedilum* sp., *Tanypus fuscus* (Diptera) colonize all stations without discrimination of the habitat (Fig. 4 A to V). Layo station is specifically colonized by eight species namely *Canthydrus minutus*, *Crocothemis* sp, *Hydrobius* sp, *Hydrocanthus micans*, *Hydrocoptus simplex*, *Yola tuberculata*, *Potamophilus* sp., (Fig. 5A to G). Banco station is characterized only by Corydalidae, *Hydroptila* sp., *Hyphydrus* sp., *Macroplea* sp. and *Protomacronema* sp. (Fig. 5 H to L). *Sperchus ceryisi*, *Sigara* sp. and *Pantala flavescens* are specific to Azaguié (Fig. 5 N to O). *Valleriola* sp., *Hydrometra* sp., *Ictinogomphus* sp. and *Ecnomus* are subservient to Anyama I (Fig. 5 P to S), while, *Aulonogyrus* sp. and *Cricotopus kisantuensis* are exclusive to Anyama II (Fig.5 T to U). One-way ANOSIM calculated significant assemblage differences between insect communities from freshwater (Anyama I, Anyama II, Azaguié and Banco) and brackish water(Layo), irrespective of location of the fish farm ponds ($R = 0.833$; $p = 0.2$). The highest value of species diversity index (H') was 2.88 at Banco station (Table 4). Pielou index (J), abundance index (λ) and Margalef index (d) of this station were 0.73, 0.09 and 5.84 respectively. The lowest value of species diversity index (H') was 1.73 at Azaguié station. The Pielou index (J), abundance index (λ) and Margalef index (d) of this station were 0.45, 0.37 and 5.17 respectively. The K-dominance curves of the five stations were given in Fig. 6. Apparently, these five stations are colonised by several insect communities. The dominance curve of Azaguié, Anyama I and Anyama II stations are located above other curves (Layo and Banco) indicating the highest dominance and the lowest diversity in these stations. Conversely, the dominance of Banco station was the lowest, and the diversity was the highest.

Table 3. List of discriminating species for among-habitat comparisons of similarity, average abundance, species-specific contribution to average dissimilarity, ratio of average species-specific contribution to dissimilarity divided by the standard deviation of contribution to dissimilarity among habitats, Co%: percentage of average dissimilarity due to species and Cu%: cumulative contribution of species to dissimilarity between the brackish (Layo) and freshwater (Azaguié, Anyama I and Anyama II) environments.

Taxa	Average abundance		Average dissimilarity	Dissimilarity /Standard Deviation	Co (%)	Cu (%)
	Brackish water	Freshwater				
Anisops sardea	3093.00	3619.75	13,80	2,36	30,44	30
Tanypus fuscus	5.00	620,00	4,43	2,21	9,78	40,21
Stictochironomus sp	0.00	539,25	4,16	1,48	9,19	49,40
Plea pullula	263.00	336,25	3,55	1,05	7,84	57,24
Canthydrus minutus	341.00	0,00	2,55	11,51	5,61	62,85
Mesovelia sp	398.00	160,00	1,71	1,56	3,77	66,62
Amphiops sp	266.00	85,00	1,55	2,20	3,42	70,04
Eurymetra sp	68.00	248,25	1,38	1,97	3,04	73,09
Nilodorum fractilobus	124.00	240,50	1,21	0,70	2,67	75,75
Clooeon bellum	303.00	139,75	1,20	2,76	2,64	78,39
Chaoborus anomalus	0.00	146,50	1,08	5,32	2,38	80,77
Diplonychus sp	159.00	37,25	0,92	4,01	2,02	82,79
Ceratopogon sp	3.00	109,00	0,78	0,70	1,72	84,52
Canthydrus xanthinus	91.00	14,00	0,58	6,87	1,27	85,79
Appasus sp	102.00	24,00	0,57	1,89	1,26	87,04
Chironomus imicola	132.00	184,50	0,54	1,00	1,19	88,23
Clinotanypus claripennis	0.00	50,75	0,38	2,61	0,85	89,08

Table 4. Number of taxa (S), abundance (N), dominance index (d), species diversity index (H'), evenness (J') and abundance index (λ).

Stations	S	N	d	H'	J'	λ
Layo	44	6104	4.93	2.17	0.57	0.27
Banco	52	6167	5.84	2.88	0.73	0.09
Azaguié	48	8940	5.17	1.73	0.45	0.37
Anyama I	46	6765	5.10	1.75	0.46	0.38
Anyama II	47	7612	5.15	1.74	0.45	0.39

Abundance of aquatic insects

The mean abundance ranged from Layo (2034.66 individuals) to Azaguié (2980.00 individuals). The mean abundance of each order was calculated. Hemiptera (7882.66 individuals) and Diptera (2757.67 individuals) dominated the faunal abundance (Table 1). They constitute 66.44 % and 23.24 % respectively of total aquatic insect abundance. Ephemeroptera (508.33) and other groups Coleoptera (482.33), Odonata (201 individuals), Trichoptera (20.33), Lepidoptera (10 individuals) and Megaloptera (0.33 individuals) comprised the remaining 10.32% of the faunal abundance. Spatially, Hemiptera dominated at all the stations. *Anisops sardea* dominated the faunal abundance at all station except Banco where *Plea pullula* was the most dominant taxon.

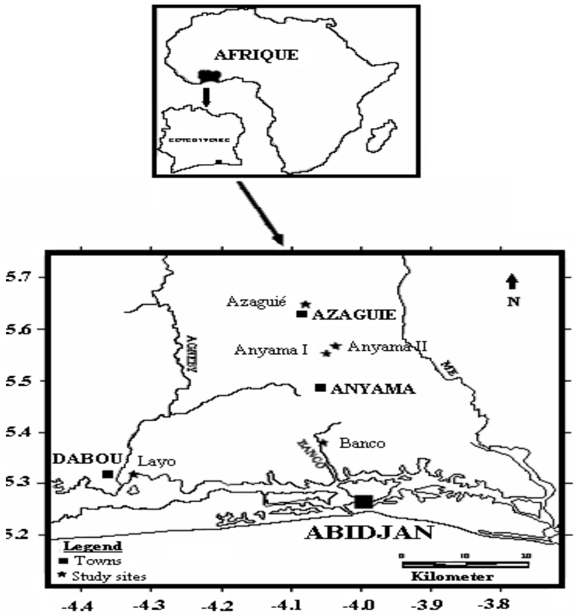

Fig.1. Location of the study area showing the different sites.

Distribution of responsible taxa which make difference between brackish water and freshwater

According to sampling area's water nature, the habitats can be divided into two groups (Table 2). The group I consisting of Layo station (brackish water) had lower aquatic insect species number (6104 individuals) and species richness (44). The group II consisting of Banco, Azaguié, Anyama I and Anyama II stations (freshwater) had higher aquatic insects' species number and species richness (Table 3). The average dissimilarity for these two habitats was 45.34%. Seventeen taxa are responsible for this dissimilarity. *Anisops sardea* represented 30% of this dissimilarity on a total of 17 species of aquatic insect.

The average similarity of freshwater group is 58.36%. The results of redundancy analysis revealed that the relationships between insect taxa and their habitat conditions follow mainly the first two axes (Fig.7). These two axes accounted for 98.4% of the total variance. Temperature, dissolved oxygen and pH were negatively correlated to axis I. At these stations, highest abundances of *Anisops sardea* and *Tanypus fuscus* were recorded. Water transparency was positively associated to axis I. The highest value of this parameter was obtained in Banco station. At this station, highest abundances of *Plea pullula* were recorded. Conductivity, nitrites and phosphates were positively correlated to axis II. The highest values of these variables were recorded in Layo station. At this station, highest abundances of *Mesovelia* sp. and *Cloeon bellum* were recorded Concerning the substrate, sand and mud were negatively and positively correlated to axis I respectively while, clay was negatively associated to axis II. Sand, mud and clay were important in Layo, Banco and Anyama I stations repectively. According to the distribution of the taxa, canonical analysis shows that *Canthydrus* *minutus*, *Canthydrus xanthinus*, *Appasus* sp., *Diplonychus* sp. and *Cloeon bellum* were associated to Layo station (brachish water), while *Amphiops* sp., *Mesovelia* sp., *Plea pullula*, *Stitochironomus* sp., *Eurymetra* sp., *Tanypu fuscus*, *Chaoborus anomalus*, *Nilodorum fractilobus*, *Clinotanypus claripennis*, *Ceratopogon* sp., and *Chironomus imicola* were correlated to Banco, Azaguié, Anyama I and Anyama II stations (freshwater).The position of *Anisops sardea* on axis I was due to the fact that the average abundance of this species is substantially equal in both habitats.

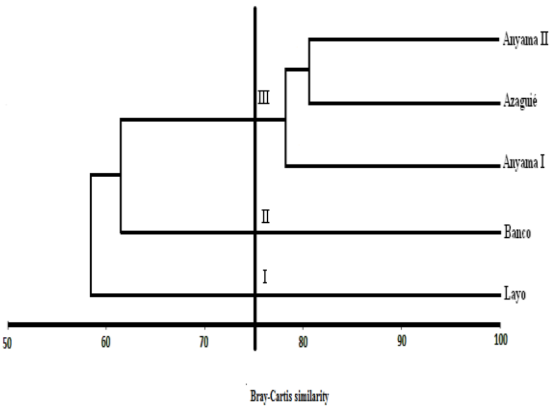

Fig. 2. Hierarchical clustering from Bray-Curtis similarities of five stations. three major groups at the similarity level of 75 %. In each group, stations 'aquatic insects abundances are significantly similar.

Fig. 3. Multidimensional scaling two-dimensional ordination plots.

Discussion

A total of 79 aquatic insect taxa belonging to 35 families and 8 orders were identified during this study. These orders are Ephemeroptera, Odonata, Hemiptera, Megaloptera, Lepidoptera, Coleoptera, Trichoptera and Diptera. Our result are similar to several studies as Angélibert *et al.,* 2004, Apinda-lognouo, 2007; Cereghino *et al.*, 2008, Ruggiero *et al.*, 2008. The comparison of our results to those obtained by Edia *et al.* (2007) in rivers Soumié, Ehania, Eholié, and Noé and Diomandé *et al.* (2009 b) in the river Agneby, we can say that with respect to their surface, the ecological value of ponds surveyed in this study is important. Indeed, these authors have collected 119 and 46 taxa respectively. Artificial ponds are ecosystems that contribute to the biodiversity of aquatic insects assemblages (Yapo *et al.*, 2007, 2012, 2013, Edia, 2013). According to Gee *et al.* (1997), the construction of artificial ponds and pools is an important measure to compensate the loss of biodiversity. The species composition of aquatic insects varied among different sampling stations. This would be linked to environmental conditions of the stations. Indeed, Banco station is located in the Banco National Park which is a primary forest. This station is less disturbed. Also, the ponds of this station were abandoned. These features could act in favor of greater taxonomic richness hosted by this station compared to those of active stations. Céréghino *et al.* (2008) emphasize that the ponds of abandoned farms tend to support a greater number of taxa. The presence of the forest around Banco station creates a good condition for the development of several species insects. The amount of plants, algae, detritus and prey increased in the course of succession, and phytophagous (*Macroplea* sp.…), algophagous (*Micronecta* sp., *Sigara* sp.…), detritophagous (*Dipseudopsis capensis*, *Hydrochara rickseckeri*…) and carnivorous (*Ranatra parvipes*, *Anisops*, *sardea*, *Pseudagrion wellani*, *Libellula* sp, *Amphiops* sp, *Cybister tripunctatus*…) species benefited alike from this development. Some studies have shown that size or density of vegetated areas are correlated with the number of macroinvertebrate species in a water body (Friday 1987; Nilsson and Söderberg 1996). The other stations are located in agricultural landscapes; they are subject to human influence. This disturbance could explain the observed low taxonomic richness in these habitats. Our results corroborate those of Karrouch & Chahlaoui (2009) which compared the influence of human activities on taxonomic richness and structure of macroinvertebrate of the Oued Boufekrane water in Morocco. The low taxonomic richness of Layo was due to the influence of the conductivity and the transparency on benthic species. Indeed in this station, the conductivity was very high and transparency very low and only five taxa were collected in the sediment, which is not the case in others stations. The lowest taxonomic richness of Layo station could be also explained according to Elouard (1981), by the fact that very few species have adapted to life in brackish environments. According to cluster analysis of species composition for different stations, three groups were found at 75 % similarity. Layo and Banco, two groups with higher domination of main dominance species differed from the other group including Azaguié, Anyama I and Anyama II with lower domination of main dominance species and the most dominant species *Anisops sardea* and many other common species. Analysis of Fig. 2 shows that the stations of Layo and Banco are separated. This position indicates that there is clearly a low level of similarity between samples of Layo and Banco. This is due to the significant difference observed between the number of taxa, the dominance index, the species diversity index, the evenness and abundance index. The majority of samples (Anyama I, Azaguié and Anyama I) appear to have high levels of similarity. The analysis of Table 4 indicates that these three stations have significantly similar number of taxa, dominance index, species diversity index, evenness and abundance index. This classification could be explained firstly by means of diversity indices and abundance recorded in the different stations and also by the importance of values of environmental parameters. The station of Layo (group I) had the lowest abundance with a higher diversity than that of Azaguié, Anyama I and Anyama II stations. As to environment factors, Layo station had the highest value of conductivity (3037.83 µS.cm^{-1}), of nitrite (1.26 mg.L^{-1}) and the highest value of phosphate (2.47 mg.L^{-1}). Layo station was characterized by five dominant species (*Appasus* sp., *Diplonychus* sp., *Cloeon bellum*, *Canthydrus minutus* and *Canthydrus xanthinus*). Banco station (group II), recorded the highest diversity. This station was caracterized by low values of dissolved oxygen (4.18 mg.L^{-1}) and pH (6.75) and high values of water Secchi transparency (30.14 cm) and ammonium (0.31 mg.L^{-1}). Five most dominant species were recorded in this station (*Amphiops* sp., *Mesovelia* sp., *Eurymetra* sp., *Plea pullula* and *Stictochironomus* sp.) Although dissolved oxygen registered at Banco is low but this value is greater than 3.5 mg / l, these water bodies are well-oxygenated (Mélard, 1999). Organisms that live in these conditions of low oxygen content would be capable of some form of anaerobic metabolism (Davis, 1975). The latter group (Azaguié, Anyama I and Anyama II) recorded the highest total abundance of individuals and the lowest diversity. As to environment factors, these three stations had similar dissolved oxygen contents (comprised between 5.71 mg.L^{-1} and 6.33 mg.L^{-1}), temperature values (between 28.8°C and 28.97°C), and water Secchi transparency (between 21.99 cm and 23.05 cm). This group was characterized by common dominant taxa such as *Ceratopogon* sp., *Nilodorum fractilobus*, *Clinotanypus claripennis*, *Chironomus imicola*, *Chaoborus anomalus* and *Tanypus fuscus*. The values of the Simpson index obtained in the different stations are low. The settlement of these stations is quite diverse. The values of the Margalef index recorded in all stations are greater than 2. In the station of Layo, this index has a value which tends to 5 while in the other stations, it is greater than 5. These results indicate that the different stations have a high biological diversity. In Layo, Azaguié, Anyama I and Anyama II stations, evenness ranged between 0.45 and 0.57. This index is less than 60 %, the threshold below which a disturbed environment is considered (Dufraise & Leuzinger, 2009). Low evenness obtained in these stations would be a sign of instability of the ponds linked to various anthropogenic disturbances. This situation would lead to dominance but also a scarcity of certain taxa. Indeed, the activities related to the operation of farms are the cause of various disturbances experienced by the ponds of these stations. The highest values of the Shannon-Wiener index were recorded at Banco and Layo stations. Both stations have a well diversified population where many taxa are numerically well represented.

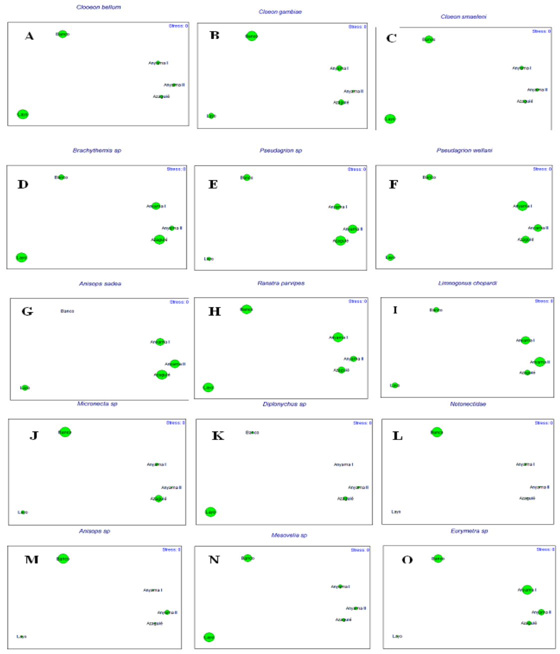

Fig. 4. Bubble plot of common species of the different stations.

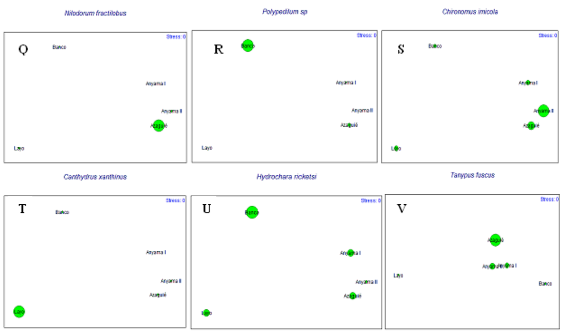

Fig. 4. Extented, Bubble plot of common species of the different stations.

In the ordination diagram (Canonical correspondence analysis) for taxa (Fig. 7), all the species were so far to centre. Their correlations distributions with environmental variables were vague or ambiguous. This distribution pattern could indicate a preference for intermediate values of the environmental variables; alternatively, it may as well be interpreted as a low correlation with these variables. It should be noted that many species are ubiquists that have no special habitat requirements. The present of *Anisops sardea* (Hemiptera) in all stations showed that this species is a cosmopolitan insect and seemed lest influenced by environmental factors.

Fig. 5. Bubble plot of specific species of Layo (A-G), Banco (H-L), Azaguié (M-O), Anyama I (P-R) and Anyama II (T-U).

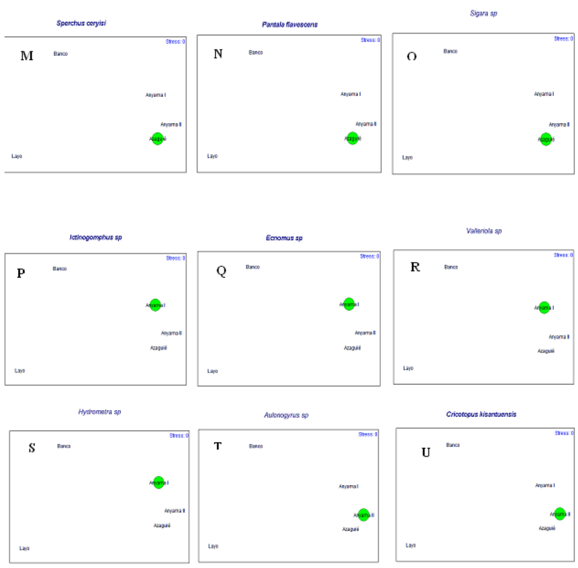

Fig. 5. Extented, bubble plot of specific species of Layo (A-G), Banco (H-L), Azaguié (M-O), Anyama I (P-R) and Anyama II (T-U).

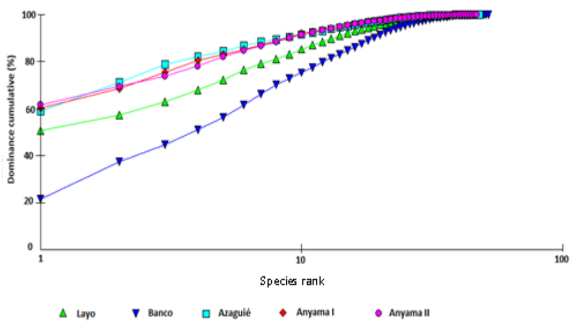

Fig. 6. K-dominance curves of five stations.

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