International Journal of Fisheries and Aquatic Research
ISSN: 2456-7248; Impact Factor: RJIF 5.44
Received: 22-01-2019; Accepted: 18-02-2019
www.fishjournals.com
Volume 4; Issue 2; April 2019; Page No. 24-31

Diversity and abundance of aquatic insects in a protected tropical Forest fishpond of Côte d'Ivoire

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Abstract
This study aimed to determine diversity and abundance of aquatic insects in a protected forest fishpond. Sampling was done monthly between December 2007 and November 2008. In the pond, water column and sediment were collected using a hand-net and a van Veen grab respectively. A total of 13,469 individuals distributed among 24 families belonging to 7 orders were recorded. Heteroptera recorded the highest number of taxa. Taxa richness ranged from 17 (Site B) to 24 (Site A). Heteroptera and Diptera were found to be the most abundant in the pond. Notonectidae and Chironomidae were the most abundant family in order Heteroptera and Diptera respectively. Shannon-Wiener diversity index, Evenness and Margalef index were higher at Site A. This study revealed that water of the pond is slightly polluted as supported by the values of biological indices and by presence of insect of orders Heteroptera and Coleoptera.

Keywords: Aquatic insect communities, Banco National Park, Biological indices, Taxa richness

1. Introduction

Diversity is the variability among living organisms from all sources including terrestrial and aquatic ecosystems and the ecological complexes of wich they are a part. This includes diversity within species, between species and of ecosystems [5]. Insects are the most diverse group of organisms in freshwater bodies. The principal groups of aquatic insects constitute an important part of the biota of the fresh water communities. Aquatic insects are important organisms in a water body ecosystem function. In addition to ecosystem function, aquatic insects are reliable indicators of human impact on freshwater ecosystem. Insects have proven to be a useful tool for testing ecological paradigms [1]. These are excellent indicators of the quality of the environment. By their presence, they tell us about the quality of the water [12, 13]. Banco National Park is a forest land area located in the town of Abidjan. This forest was erected as National park in 1953. 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 forest has a recreational value. It is rich in plant and animal life. It is an habitat for many birds, monkeys and chimpanze. The existence of Banco forest allows a reliable groundwater recharge of the aquifer that fed the river. It also protects this aquifer that supplies water for the population of Abidjan [18]. Tourism has been developed there. Banco forest is a wonderful tourist sanctuary unknown to the Ivorian public. There is an arboretum of a variety of tree species such as Niangon, mahogany and avodires. There is also the first forestry school of the West African sub-region, the former governor's house, a fish farm and a mini zoo which has closed its doors. The fish farm which has been temporarily abandoned contains about fifteen ponds. A fish pond is a controlled pond, artificial lake, or reservoir that is stocked with fish and is used in aquaculture for fish farming, or is used for recreational fishing or for ornamental purposes. In Côte d'Ivoire, available literature concerning macroinvertebrates from ponds located in conservation areas is scarce. Despite this forest is located in Abidjan, where access is not as difficult, very few studies have been conducted in it [2, 4, 24, 25, 26, 27, 28, 29]. 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 describe the diversity and the abundance of aquatic insect community of the fishpond (ii), to investigate the relationships between insect's fauna richness and environmental variables and (iii) to determine water quality using diversity indices such as Margalef and Shannon-Wiener indices.

2. Materials and Methods

2.1. Study site

The study was undertaken in a fish farm pond located in Banco National Park (5° 23′ 40″ N, 4° 03′ 07″W), a primary forest wich is nestled in the heart of the Ivorian economic capital, between four municipalities (Adjamé, Attécoubé, Abobo and Yopougon). Banco National Park (Figure 1) covers an area of 3,474 hectares.This park is characterized by four seasons (two dry seasons and two rainy seasons) The dry seasons extends from December to March and from August to September while the rainy seasons extends from April to July and from October to November. In this park, there is a fish farm pond wich is abandonned by the authorities. The ponds were fed by Banco river. They were permanent and shallow (depth<1 m). The study pond area was 1000 m^2. Bottom sediment was mostly composed by mud. The pond contained some macrophytes as water Hyacinths, *Eichhornia crassipes*. It was abandoned and not contained fish.

2.2 Measurement of Environmental Variables
On each sampling campaign, 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 campaign, filtered through GF/C Whatman® filters, frozen upon arrival at laboratory. Analyses of dissolved inorganic nutrients: ammonium, nitrite and phosphate were carried out according to Grasshoff *et al*. [10].

2.3 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 [6, 7, 8, 21].

2.4 Statistical Analysis
In each sampling site, abundance, Shannon-Wiener diversity index (bits) [19]. Pielou Evenness [17]. Margalef and Berger-Parker indices were calculated. Shannon-Wiener diversity index was used to quantify taxonomic richness and distribution of taxa in the communities. According to Margalef [15], H' varies between 0, in the case where the settlement consists of only one species, and $\log_2 S$ in the case where all the species present are with a similar abundance. 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 [3]. This index allows to better estimate the absolute richness, regardless of the sample size [16]. In the present investigation, the Margalef diversity index was used to assess the ecological quality of the environment according to Lenat *et al.* [14]. Analysis of variance (ANOVA) was used to determine effects of sites on environmental variables, Shannon-Wiener diversity, evenness 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. Anova test, Figure, Shannon-Wiener, Pielou evenness, Margalef and Berger-Parker indices were performed using Statistica 7.1 and PAST 3.1.0 sofwares. 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 for 499 permutations. Taxa which represented at least 0.40% 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. Spearman's correlation analysis was used to determine the magnitude of the significance and nature of the relationship between environmental variables and diversity indices and Taxa richness.

3. Results and Discussion
3.1 Environmental Variables
Mean values of selected physicochemical parameters of water quality of the study pond in the four sampling sites are presented in Table 1. Water Temperature ($F_{3,48}$=2.83; P=0.048) and pH ($F_{3,48}$=3.70; P=0.018) were significantly different. Conductivity, Dissolved Oxygen, Water Transparency, Nitrite, Ammonium and Phosphate were not notably different during the period of study (p>0.05) using ANOVA. Temperatures mean value oscillated from 27.21ºC (Site C) to 28.04ºC (Site D). Transparency varied from 28.77cm (Site B) to 30.55cm (Site A). The lowest mean value of Dissolved Oxygen (4.11 mg/L) was found in Site A and the highest values were observed in Site B (4.17 mg/L). Regarding the pH, the water of Site C and Site D were slightly acid with low variation of the recorded figures ((6.74 (Site C) and 6.95 (Site D)). The highest mean value of conductivity (37.13µS/cm) was observed at Site D and the lowest was observed at Site B (35.71µS/cm). The mean dissolved nutrients, Nitrite, Ammonium and phosphate concentrations ranged from 0.61 mg/L (Site A) to 1.23 mg/L (Site D), 0.24 mg/L (Site B) to 0.37 mg/L (Site A) and 1.82 mg/L (Site A) to 2.23 mg/L (Site C), respectively.

3.2 Aquatic insect composition and abundance
A total of 13 469 individual aquatic insects were recorded, distributed among 24 families with 7 orders belonging to Coleoptera, Heteroptera, Diptera, Odonata, Ephemeroptera Trichoptera and Lepidoptera (Table 2). Heteroptera was the most diversified order representing 9 families, followed by Coleoptera (5 families), Diptera (3 families), Odonata (2 families), Epheroptera (2 families), Trichoptera (2 families) and Lepidoptera (1 family). Heteroptera recorded the highest abundance with 8 655 individuals (64.26% of total abundance). This order was followed by Diptera, Ephemeroptera and Coleoptera with 26.41%; 3.71% and 3.25% respectively. Lepidoptera with 0.01% of total abundance recorded the lowest abundance. Based on abundance, Notonectidae was the most important family. It was followed by Chironomidae. In Site B, Site C and Site D, the most abundant family was Notonectidae 52.82% ; 55.75% and 65.54% of total abundance respectively, whereas in Site A, Pleidae with 26.82% of total abundance was the most important family. Family Chironomidae hold the second position after Notonectidae in the different Sites. This family was followed by Gerridae in Site B (3.31%), Site C (7.53%) and Site D (4.72%). In Site A Chironomidae was followed by Pleidae (26.82%), Hydrophilidae (8.47%) and Baetidae (7.43%). Based on abundance the different Sites were shared out into three groups among them (Figure 2) : Group I was constitued by Site D and Site C, Goup II was constitued by Site B and Group III was constitued by Site A. The family abundance evolution was conveyed by a

plot matrix (Figure 3). This figure indicates that the majority of the families harvested in the different sites have a low abundance. In site A, only two families (Pleidae and Chironomidae) have an abundance beyond 676 individuals. In site B a family has an abundance that tends to $1.35.10^3$ individuals and another has an abundance beyond $2.03.10^3$ individuals. These are Chironomidae and Notonectidae respectively. In Site C, there is only one family whose abundance tends to $2.03.10^3$ individuals. This is Notonectidae family. In Site D, only one family has an abundance greater than $2.03.10^3$ individuals. This is Notonectidae family. The Abundance Distribution Model (Figure 4) goes in the same direction as the evolution of abundance. This figure indicates that in Site A, the majority of families have an abundance of less than 100 individuals, 5 families have an abundance of between 100 and 300 individuals, while 2 families have an abundance of more than 800 individuals. In Site B, most families have an abundance of less than 100 individuals, one family has an abundance of over 1000 individuals, and another has an abundance of more than 2000 individuals. In Site C, all families have an abundance of less than 100 individuals, one families has an abundance greater than 600 individuals, and another has an abundance of more than 1600 individuals. In Site D, one family has an abundance greater than 600 individuals, another has an abundance greater than 2000 individuals, whereas the remaining one have an abundance of less than 100 individuals.

3.3 Taxa richness and diversity

Taxa richness calculations for the different sites showed a range of 17 (Site B) to 24 (Site A) (Table 3). There was a significant difference in taxa richness between the sampling sites (F=26.25 ; P=0.00). Shannon-Wiener diversity index (H') showed a range of 1.20 (Site D) to 2.22 (Site A) (Table 3). These results also displayed a significant difference in Shannon-Wiener index among sampling sites (F=53.51 ; P=0.00). The Pielou evenness varied from 0.41 (Site D) to 0.70 (Site A). There was a significantly difference between the different sites in Pielou Evenness (F=30.37 ; P=0.00). Margalef index oscillated between 1.94 (Site C) and 2.82 (Site A). This index was significantly different between the different samplinbg sites (F=24.92 ; P=0.00). Berger-Parker index was lower in Site A and higher in Site D. Table 4 shows that Taxa richness had a considerable positive relationship with Water transparency ($r=0.304$, $p<0.05$) and a negative correlation with nitrite ($r=-0.325$, $p<0.05$). Shannon-Wiener index was negatively correlated with nitrite ($r=-0.295$, $p<0.05$). Margalef index was negatively correlated with nitrite ($r=-0.343$, $p<0.05$). Meanwhile, Pielou evenness had a negative relationship with pH ($r=-0.285$, $p<0.05$).

3.4 Relationships between Environmental Variables and Aquatic Insect Communities

The results of redundancy analysis revealed that the relationships between insect's families and their habitat conditions follow mainly the first two axes (Figure 5). These two axes accounted for 97.18% of the total variance. This analysis makes it possible to associate with axis I a negative gradient of mineralization. This axis is negatively correlated with factors such as conductivity and Nitrite. This axis opposes sites C and D in the left side and Site A in the right side. High values of Nitrite and Conductivity were observed in Site D. Notonectidae and Libellulidae select environment with higher Nitrite and higher Conductivity respectively. These taxa characterized Site D. Axis II is negatively correlated with Transparency. Maximum values for this parameter were obtained in Site A and Site C. Mesoveliidae and Nepidae preferred higher transparent water. Site A is characterized by taxa such as Coenagrionidae, Corixidae, Pleidae, Baetidae and Hydrophilidae. Site B is characterized by the taxa Chironomidae, Belostomatidae, Chaoboridae and Dytiscidae. In Site C, is mainly observed Gerridae.

3.5 Discussion

This study revealed the presence of 24 families with 7 orders belonging to Coleoptera, Heteroptera, Diptera, Odonata, Ephemeroptera Trichoptera and Lepidoptera in the pond located in Banco National Park. These orders are generaly those were observed in ponds [13, 24-29]. The diversity of aquatic insects is also significantly high in comparison to some studies in lentic water bodies inhabiting insects of the world. Indeed, Hasan, *et al.* [13] investigated 13 families and 6 orders in three permanent ponds of Guwahati in Assam (India), Vasantkumar and Roopa [22] reported 15 species belonging to 6 orders in a pond ecosystem in Karwar (India). Order Heteroptera recorded the highest number of taxa. In the present study order Heteroptera was found the most diverse, this order composed of 37.5% of total number of taxa collected. It followed by Coleoptera, Diptera and Odonata. Similar patterns have been observed by Hasan *et al.* [13] who studied the Biodiversity of aquatic insect population in three permanent ponds of Guwahati in Assam (India). Heteroptera and Diptera recorded the highest abundance. They represented 64.26% and 26.41% of total aquatic insect abundance respectively. Order Heteroptera was found to be the most abundant in the pond. Notonectidae was the most abundant family in order Heteroptera. In order Diptera, Chironomidae recorded the most important abundance. This family was followed by Chaoboridae. Abundance of Chaoboridae is similarly equal in Site A, Site C and Site D. It is a bit more important in Site B. The presence of these insects is due to the fact that the pH of the water in this pond is slightly acid. Indeed, Diptera Chaoboridae are insects that are fond of acidic waters. The environmental effect which is water transparency influences the richness of aquatic insects. A positive correlation between transparency and taxonomic richness and diversity indices was observed during this study. Indeed, the highest taxonomic richness and diversity indices have been recorded in site A where transparency is the most important. Temperature was positively correlated to abundance, taxa richness and Margalef index. Conductivity was positively correlated to taxa richness and Margalef index and significatively correlated to abundance. TDS was positively correlated to taxa richness and Margalef index. It also significatively and positively correlated to abundance. Macrophytes was significatively and positively correlated to abundance, taxa richness and Margalef index. It also correlated to shannon-Wiener index. Presence or absence of macrophytes in the pond found to be important factors and that is affecting in the distribution and abundance of aquatic insects in the water bodies. Indeed, in the Site A and B Macrophytes were very abundant and the investigation revealed that the highest taxa richness and abundance were recorded in these sites respectively. A study about diversity and abundance of aquatic macroinvertebrates in Brazil reports that the sampling station with the highest dissolved oxygen level had the highest Shannon-Weiner diversity index [20]. In this study, site A where the lowest value of dissolved oxygen was observed records the highest values of the diversity indices. It should be noted that this value of oxygen is low in site A, but it is not significantly different from the dissolved oxygen values of the other sites. Evenness index values are low in sites B, C and D. They ranged from 0.41 to 0.50. These low values would reflect an unbalanced settlement in these sites while the A site with a value of 0.70 showed a balanced settlement. In this site, evenness index was greater than 0.60, so the environment is not disturbed [9]. Indeed, in site B, C and D, Heteropterans of family Notonectidae numerically dominated the insecta settlement collected. Wilhm and Dorris [23] set the diversity index of less than 1 for highly polluted, 1 to 3 for slightly polluted and greater than 4 for unpolluted water bodies. In our case, Shannon-Wiener diversity index ranged from 1.20 to 2.22 (Table 3). All sampling sites in this study were shown as slightly polluted using this scale. According to Lenat *et al.* [14] 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. The present investigation showed that Margalef Diversity Index value oscillated from 1.94 to 2.82. All the sites are therefore considered to be moderately polluted. In this study, a total of 24 families was recorded from the different sites of the pond ecosystem and the number of aquatic insect species and their abundance varied among the sites. Heteropterans and Coleopterans dominated the taxa richness. Dominance of Heteropteran and Coleopteran insect suggested that the pond ecosystem of Banco National Park is relatively less polluted. In view of these three types of observations, we can say that the water in this pond is moderately polluted. Aquatic insect diversity in Banco national Park pond could have been affected by the presence of pollution in the river. Indeed, Banco river that feeds the ponds of this forest has its source to Abobo, passes to the neighborhoods to the civil prison. This water is loaded with garbage from these neighborhoods. This waste could cause pollution of this water, resulting in the moderate pollution observed in this pond.

Table 1: Physicochemical characteristics (mean ± (SD)) of water at the different sampling sites.

Parameters	Site A	Site B	Site C	Site D
Transparency	30.55 ± 5.58^{a}	28.77 ± 2.60^{a}	30.10 ± 2.00^{a}	29.05 ± 2.2^{a}
Temperature	27.28 ± 0.54^{a}	27.22 ± 0.58^{a}	27.21 ± 0.61^{a}	28.04 ± 1.30^{b}
Conductivity	35.93 ± 2.74^{a}	35.71±2.62	35.90±3.45	37.13±2.58
Disolved Oxygen	4.11 ± 1.15^{a}	4.17 ± 1.22^{a}	4.14 ± 1.13^{a}	4.13 ± 0.93^{a}
pH	6.75 ± 0.23^{a}	6.77 ± 0.17^{ab}	6.74 ± 0.19^{a}	6.95 ± 0.09^{b}
Nitrite	0.61 ± 0.59^{a}	1.08 ± 0.87^{a}	1.09 ± 0.9^{a}	1.23 ± 0.93^{a}
Ammonium	0.37 ± 0.29^{a}	0.24 ± 0.30^{a}	0.25 ± 0.33^{a}	0.24 ± 0.32^{a}
Phosphate	1.82 ± 0.60^{a}	2.18 ± 1.00^{a}	2.23 ± 0.93^{a}	2.11 ± 1.17^{a}

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

Table 2: Aquatic insect abundance recorded in the different samplig sites of the Pond.

Order Name	Family Name	Site A	Site B	Site C	Site D	Total
Coleoptera	Hydrophilidae	293	10	5	11	319
	Dytiscidae	15	22	4	14	55
	Elmidae	16	1	2	2	21
	Curculionidae	9	0	1	2	12
	Chrysomelidae	31	0	0	0	31
Heteroptera	Belostomatidae	64	47	2	10	123
	Gerridae	173	126	234	146	679
	Corixidae	94	65	37	18	214
	Notonectidae	224	2010	1733	2029	5996
	Naucoridae	22	0	2	0	24
	Pleidae	928	16	0	0	944
	Mesoveliidae	246	24	166	29	465
	Veliidae	3	1	4	0	8
	Nepidae	59	40	63	40	202
Diptera	Chironomidae	852	1208	651	607	3318
	Chaoboridae	54	73	53	54	234
	Tabanidae	3	0	0	2	5
Odonata	Coenagrionidae	63	53	55	42	213
	Libellulidae	15	21	21	16	73
Ephemeroptera	Baetidae	257	87	74	65	483
	Polymitarcyidae	11	1	1	4	17
Trichoptera	Polycentropodidae	26	0	0	4	30
	Hydroptilidae	1	0	0	0	1
Lepidoptera	Crambidae	1	0	0	1	2
Total=7	24	3460	3805	3108	3096	13469

Table 3: Taxa richness, abundance and diversity indices of aquatic insects collected in the different sites of the pond.

	Site A	Site B	Site C	Site D
Taxa richness	24	17	18	19
Abundance	3460	3805	3108	3096
Shannon-Wiener index	2.22	1.34	1.44	1.20
Margalef	2.82	1.94	2.11	2.24
Pielou Evenness	0.70	0.47	0.50	0.41
Berger-Parker	0.26	0.53	0.55	0.65

Table 4: Spearman's correlation coefficient between selected physicochemical factors and aquatic insect abundance, Taxa richness and diversity indices in the different study sites.

Parameters	Abundance	Shannon-Wiener	Taxa Richness	Evenness	Margalef
Transparency	-0.125	0.131	0,028	0,070	0,085
Temperature	0.188	-0.269	0,155	-0,327*	0,128
Conductivity	0.336*	-0.396*	0,163	-0,419*	0,088
D. Oxygen	0.203	-0,292*	0,064	-0,256	-0,039
pH	0.269	-0,156	0,142	-0,320*	0,096
Macrophytes	0.774*	0,016	0,765*	-0,605*	0,616*
TDS	0.399*	-0,274	0,233	-0,371*	0,149
Nitrite	-0.035	-0,198	-0,054	-0,070	-0,024
Ammonium	-0.167	0,290*	0,136	0,166	0,220
Phosphate	-0.211	-0,054	-0,201	0,126	-0,177

*****. Correlation is significant at the 0.05 level

4. Conclusion

Twenty-four families of aquatic insect in a protected forest fishpond were identify. The settlement was dominated by Heteroptera in term of taxa richness and abundance. The highest taxa richness and abundance were respectively recorded in site A and B where macrophytes were very abundant. Shannon-Wiener diversity index, Pielou evenness and Margalef index were higher in Site A. This study revealed that water in the pond is slightly polluted as supported by the values of biological indices and by presence of insect of orders Heteroptera and Coleoptera.

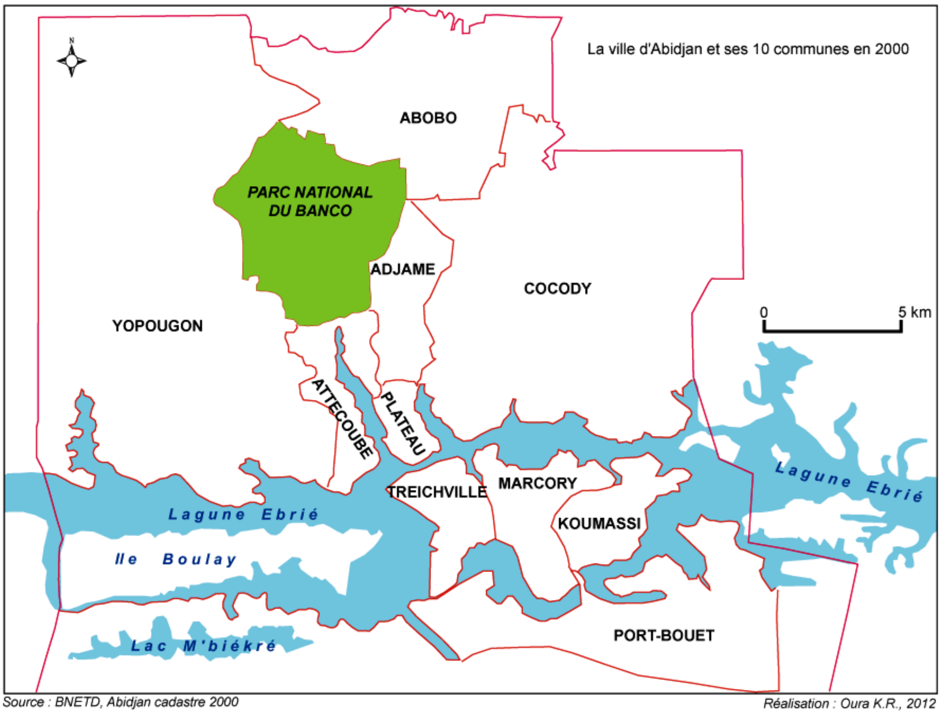

Fig 1: Location of Banco National Park (in green color; source : BNETD, Abidjan Cadastre 2000).

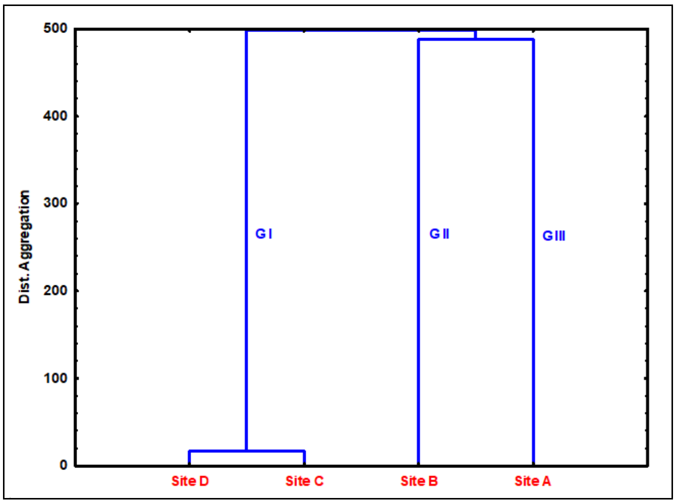

Fig 2: Hierarchical classification of the different study sites based on aquatic insects abundance.

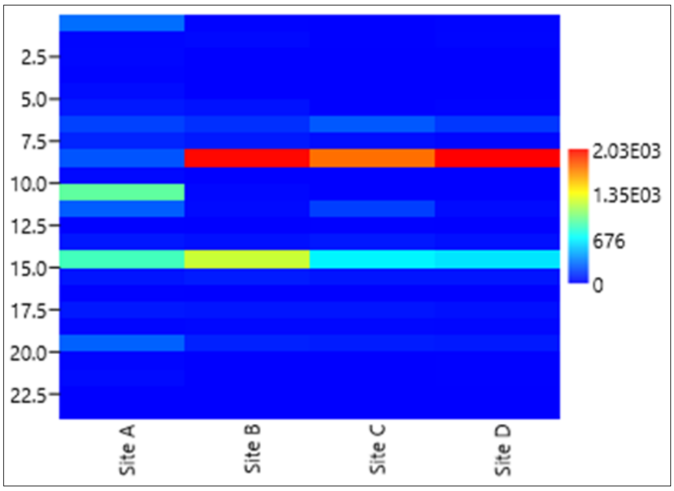

Fig 3: Plot matrix showing family abundance evolution in the different study sites

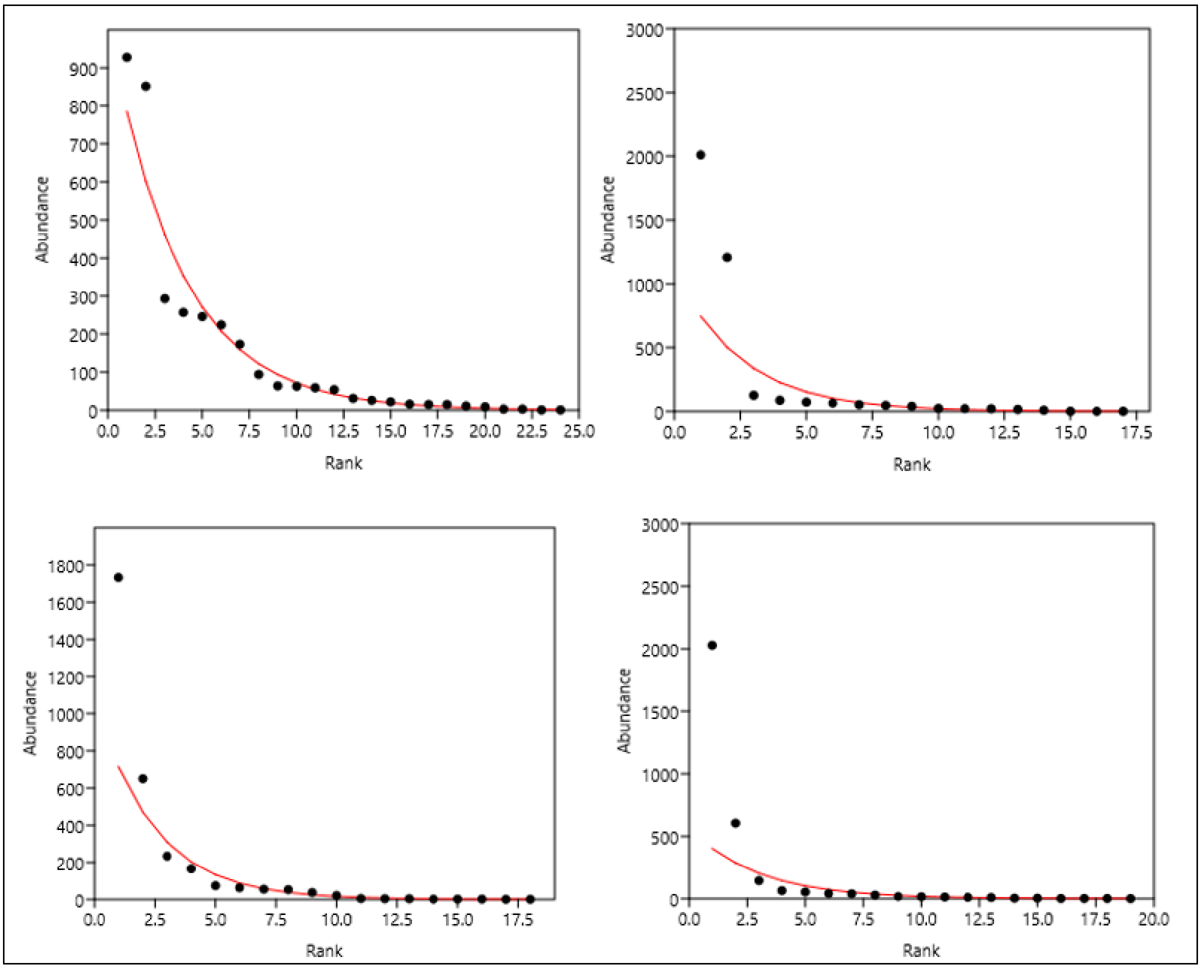

Fig 4: Abundance distribution Model of aquatic insects recorded in the different sites of the pond.

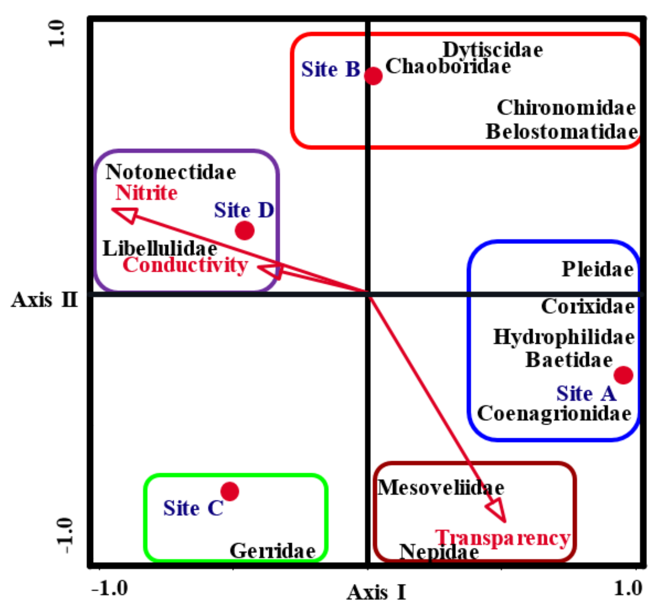

Fig 5: Canonical correspondence analysis carried out with selected environmental variables and with the dominant insect families.

5. Acknowledgements
I thank the «Office Ivoirien des Parcs et Reserves» and the «Ministère des Eaux et Forêts et
de l'Environnement» who allowed me access to the Reserve of Banco.

6. References
1. Batzer DP, Wissinger SA. Ecology on insect communities in non-tidal wetlands. Annual Review of Entomology. 1996; 41:75-100.
2. Bony YK, Kouassi NC, Diomandé D, Gourène G, Verdoit-Jarraya M, Pointier JP. Ecological conditions for the spread of the invasive snail Physa marmorata (Pulmonata: Physidae) in Ivory Coast. African Zoology. 2008; 43:53-60.
3. Boudouresque CF. Méthode d'étude qualitative et quantitative du benthos (en particulier du phytobenthos). Tethys. 1971; 3(1):79-104.
4. Camara AI, Diomandé D, Bony KY, Ouattara A, Franquet E, Gourène G. Diversity assement of benthic macroinvertebrate communities in Banco National Park (Banco stream, Côte d'Ivoire). African Journal of Ecology. 2012; 50:205-217.
5. Convention sur la diversité biologique, art. 2, 1992.
6. Dejoux C, Elouard JM, Forge P, Malsin J. Catalogue iconographique des insectes aquatiques de Côte d'Ivoire. Rapport ORSTOM, 1981, 179.
7. de Moor IJ, Day JA, de Moor FC. Guide to the Freshwater Invertebrates of Southern Africa. Volume 7: Insecta I : Ephemeroptera, Odonata & Plecoptera. Rapport N° TT 207/03 Water Research Commission, South Africa, 2003a, 288.
8. de Moor IJ, Day JA, de Moor FC. Guide to the Freshwater Invertebrates of Southern Africa. Volume 8: Insecta II : Hemiptera Megaloptera, Neuroptera, Trichoptera & Lepidoptera. Rapport N° TT 214/03 Water Research Commission, South Africa, 2003b, 209.
9. Dufraise A, Leuzinger U. La collecte du bois de feu dans le village néolithique d'Arbon Bleiche 3 (lac de Constance, Suisse) : gestion du bois et déterminismes. Bulletin de la Société Française. 2009; 106(4):785-802.
10. Grasshoff K, Ehrhardt M, Kremling K. Methods of seawater analysis, 2nd rev. and extended ed. Verlag Chemie, Weinheim, 1983, 419.
11. Hamilton AL. Saether OA. The occurrence of caracteristc deformities in the chiromomid larvae of several Canadian lakes. The Canad. Entomolog. 1971; 103:363-68.
12. Hardersen S. The role of behavioural ecology of damselflies in the use of fluctuating asymmetry as a bioindicator of water poppution. Ecolog. Entomol. 2000; 25:45-53.
13. Hasan I, Haloi DJ, Chetri S, Begum S. Biodiversity of aquatic insect population in three permanent ponds of Guwahati, Assam, India. International Journal of Fisheries and Aquatic Studies. 2016; 4(6):271-275.
14. Lenat DR, Smock LA, Penrose DL. Use of benthic macroinvertebrates as Indicators of Environmental Quality. *In*: Douglass L.W. (ed.), Biological Monitoring for Environmental Effects, Lexington books, Toronto, 1980, 97-114.
15. Margalef R. Information Theory in Ecology. General Systems. 1958; 3:36-71.
16. Peet RK. The measurement of species diversity. Annual Review of Ecology and Systematics. 1974; 5:285-307.
17. Pielou EC. The mesurment of diversity in different types of biological collection. Journal of Theoritical Biology. 1966; 13:131-144.
18. Schueler A. The Banco National Park, in Abidjan (Côte d'Ivoire), 2014. https://gc21.giz.de/ibt/var/app/wp342P/1844/index.php/elbwiesen/. 30 August 2018.
19. Shannon CE, Weaver W. The mathematical theory of communication. Urbana Illinois Press (USA), 1949, 117.
20. Silva FL, Moreira DC, Ruiz SS, Bochini GL. Diversity and abundance of aquatic macroinvertebrates in a lotic environment in Midwestern São Paolo State, Brazil. Ambi-Agua, Taubaté. 2009; 4(1):37-44.
21. Tachet H, Richoux P, Bournaud M, Usseglio-Polatera P. Invertébrés d'eau douce: systématique, biologie, écologie: CNRS Editions, Paris, 2003, 587.
22. Vasantkumar B, Roopa SV. Physico-chemical and aquatic insects diversity of pond ecosystem in Karwar, India, 2014.
23. Wilhm JL, Dorris TC. Biological parameters of water quality criteria. Bioscience. 1968; 18(6):477-481.
24. Yapo ML, Atsé BC, Kouassi P. Composition, abundance and diversity of aquatic insects in fishponds of southern Ivory Coast, West Africa. Faunistic Entomology. 2013; 66:123-133.
25. Yapo ML, Edia OE, Yté W, Atsé BC, Kouassi P. Diversity and distribution Patterns of aquatic insects in fish farm ponds in south Côte d'Ivoire. Journal of Biodiversity and Environmental Sciences. 2014a: 4(5):335-348.
26. Yapo ML, Sylla S, Edia OE, Atsé BC, Kouassi P. Spatial variation of aquatic Insect community in fish farms pond in the southern Côte d'Ivoire, West Africa. International Journal of Biosciences. 2014b; 4(10):309-321.
27. Yapo ML, Atsé BC, Kouassi P. Diversity and Community Structure of Benthic Insects in Fish Farm Ponds in Southern Côte d'Ivoire, West Africa.

American Journal of Experimental Agriculture. 2015; 5(1):82-93.
28. Yapo ML, Koné M, Tuo Y. 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. International Journal of Scientific Engineering and Applied Science. 2016; 2(11):1-16.
29. Yapo ML, Edia OE, Sylla S, Atsé BC, Kouassi P. Structure du peuplement en insectes des étangs de pisciculture au Sud de la Côte d'Ivoire (Layo, Banco, Azaguie, Anyama I, Anyama II). Afrique Science. 2017; 13(2):45-61.