

# Diversity and Community Structure of Benthic Insects in Fish Farm Ponds in Southern Côte d'Ivoire, West Africa.

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## Authors' contributions

This work was carried out in collaboration between all authors. MLY designed the study, wrote the protocol and the first draft of the manuscript; BCA managed the analyses of the study; PK managed the literature searches. All authors read and approved the final manuscript.

## ABSTRACT

**Aims:** The objective of this study is to identify the commonly occurring benthic insect fauna and workout their abundance, diversity, evenness, and degree of similarity in five fish farm ponds in southern Côte d'Ivoire.

**Study design:** Sampling was done in three ponds per station. In each pond, samples were collected monthly in sediment using a Van veen grab.

**Place and Duration of Study:** Benthic insect diversity and community structure were studied from December 2007 to November 2008 in five fish farm ponds (Layo, Banco, Azaguié, Anyama I and Anyama II) in Southern Côte d'Ivoire.

**Methodology:** Samples were taken in six replicates. The six replicates were pooled to constitute a sample for each pond.

**Results:** In total, 31 taxa belonging to 18 families and 7 orders have been recorded. Diptera was qualitatively and quantitatively the major benthic insect taxa collected in each station. Family Chironomidae dominated aquatic insect population in terms of species richness and abundance. *Nilodorum fractilobus*, *Chironomus imicola*, *Stictochironomus* sp., *Tanytus fuscus* and *Ceratopogon* sp. were the dominant taxa. Species diversity and evenness indices fluctuated from season to season and from one sampling site to other. The maximum Shannon-Weaver diversity and evenness indices were observed in Anyama II station, while the highest value of Simpson index was recorded in Layo. The Sorensen and Renkonen similarity indices showed that insect community in the different stations had an important similarity. Certain environmental parameters influenced the variation in density of benthic insects in the fishponds.

**Conclusion:** The species reported for the first time complete the list of insects' species from Ivorian aquatic ecosystems.

**Keywords:** fish farm ponds, benthic insects, diversity, community structure

## 1. INTRODUCTION

Aquatic insect species form complex communities with multiple functional feeding groups that fulfil essential ecological roles at several trophic levels (Merritt et al., 1996). Insects with their abundance and diversity dominate fresh water ecosystem (Jana et al., 2009). However, the insect fauna of aquatic ecosystem in Côte d'Ivoire is rather poorly documented. Little number of studies has been carried out on the ecological and systematic aspects of aquatic entomofauna. Unfortunately the vast majority of this work was undertaken in running water and was also carried out in the northern part of the country. In the south part, there is very little literature on aquatic insects (Dejoux et al., 1981; Diomandé et al., 2009; Diétoa, 2002; Edia et al., 2007, 2010; Edia, 2008; Kouadio et al., 2008). Fishpond complexes are important hot-spots for biodiversity. Aquatic invertebrates play a central role in the fishpond ecosystem as a major food resource for many predatory organisms (Broyer and Curtet, 2010). Ponds are habitats of critical importance for many aquatic insect species; however, very little attention has been given to natural or artificial ponds ecosystems. In Côte d'Ivoire, fishpond ecosystem has yet been no hydrobiological study, so the analysis of insect populations of ponds remains whole. To our knowledge, so far, no work has been done on the qualitative ecology of the aquatic insects in artificial ponds. In the afore-mentioned context the present study was carried out with the objective to identify the commonly occurring insect fauna and workout their abundance, diversity, evenness, and degree of similarity in five fish farm ponds in southern Côte d'Ivoire.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

This study was undertaken in five fish farms 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. 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 contained primary forest. In Azaguié, Anyama I and Anyama II, ecosystems were constituted by 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<sup>-1</sup> (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. Ponds area varied from 280m<sup>2</sup> to 500m<sup>2</sup>. 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.

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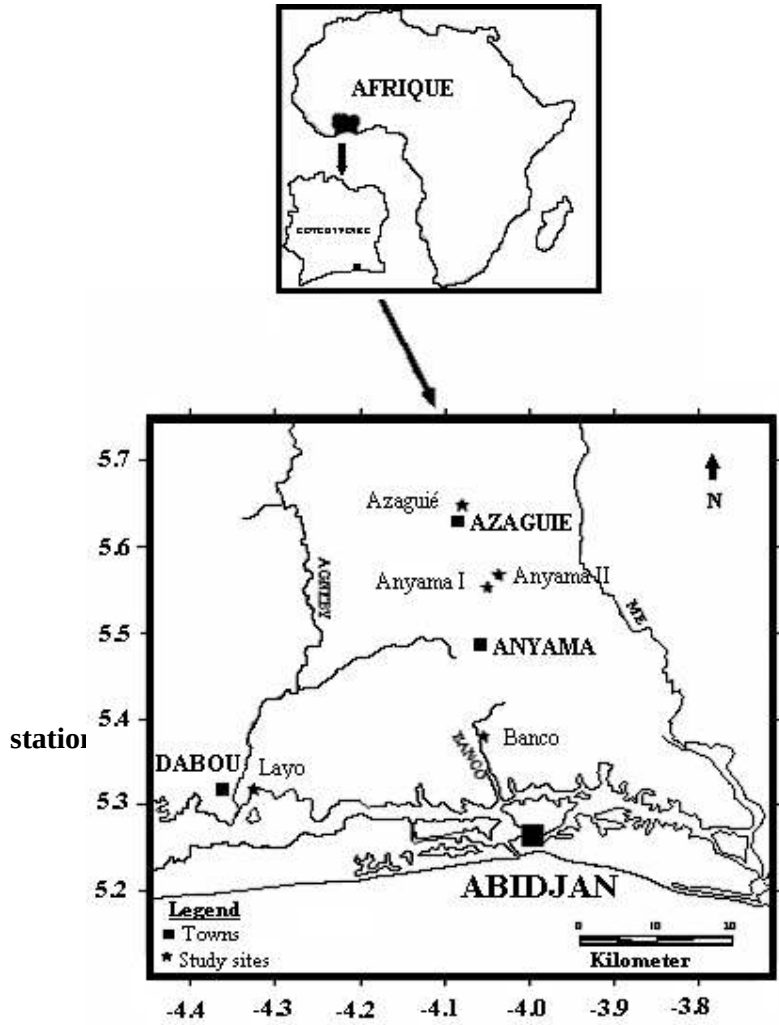


Fig.1. Location of the study area showing the different sampling stations

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**2.2 Measure of Environmental Variables**

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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 **determine** 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,  $\text{NH}_4^+$ ; nitrite,  $\text{NO}_2^-$  and soluble reactive phosphorus,  $\text{PO}_4^{3-}$ ) from filtered samples were carried out according to Grasshoff et al. (1983).

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**2.3 Sampling Procedure**

147 In each pond, monthly samples were taken in six replicates  Van veen grab  
148 (area = 0.09 m<sup>2</sup>) between December 2007 and November 2008. The samples  
149 collected were sieved through 1 mm aperture size sieve. The six samples were  
150  pooled and the remaining materials were preserved in plastic bottles containing  
151 10% formalin. In the laboratory, specimens were sorted and identified under a  
152 stereo binocular microscope to the lowest possible taxonomic level, by use of  
153  systematic and classification keys (Dejoux et al., 1981; Tachet et al., 2003; de Moor  
154 et al., 2003 a; 2003 b). Insects were counted and numbers of each species were  
155 expressed as organisms.m<sup>-2</sup>. Biomass (dry weight; mg.m<sup>-2</sup>) **were** estimated after  
156 desiccation to constant weight for 24 h at 60°C according to Mathooko (2001).  
157 Mean densities (individuals.m<sup>-2</sup>) and mean biomass were calculated for each  
158 season and for overall total study period.

## 159 2.4 Statistical Analysis

160 In each sampling station, abundance, density, Shannon-Weaver diversity index,  
161 Simpson index and Evenness index  were estimated. Coefficient of similarity was  
162 estimated following Sorensen (1948) and Renkonen (1938). Significant differences  
163 in density, Shannon-Weaver diversity, Simpson index and evenness were  
164 determined using ANOVA test. Analyses were conducting using R 2.13.1 software.  
165 Dominance (Do) as most abundant taxa numerically of different species was  
166 described on the basis of relative abundance. Moreover, relationships between the  
167 distribution and density of aquatic insects and environmental variables for all the  
168 five sampling stations were determined by Canonical Correspondence Analysis  
169 (CCA) using CANOCO 4.5 software. Taxa which obtained at least 0.2% of the total  
170 abundance in benthic environment were included in the analysis. These taxa were  
171 considered as principal taxa. This **has been**  done to minimize the influence of rare  
172 taxa.

## 173 3. RESULTS AND DISCUSSION

### 174 3.1. Physical and chemical variables

175 The temporal variation of the environmental variables **was** shown by Fig. 2. The  
176 average temperature oscillated between 27.2°C (Banco) and 28.9°C (Azaguié).  
177 The temporal variation showed that the maximum values of this parameter were  
178 recorded in the dry season during March (Layo, Banco, Azaguié and Anyama I)  
179 and during August (Anyama II). Overall, the different ponds were **much**  
180 oxygenated. The mean values were **superior** to 4.18 ±1.15 mg/l. The maximum  
181 values of dissolved oxygen were recorded during **Mars** (Layo, Banco, Anyama I),  
182 during July (Azaguié) then during **september** and October (Anyama II). The mean  
183 values of pH fluctuated between 6.75±0.19 (Banco) and 7.08±0.12 (Anyama I).  
184 This abiotic variable was significantly recorded in the dry season during September  
185 (Layo, Banco and Anyama II) and in the rainy season during October (Azaguié) and  
186 during November and July (Anyama I). The station of Layo recorded the highest  
187 value of electrical conductivity (**3037.83 ±2980.25 µS/cm**). The highest values were  
188 monthly observed in the dry season during February (Azaguié, Anyama I) and  
189 March (Layo, Banco, Anyama II). Concerning the secchi transparency, Banco  
190 presented the **strongest** value (30.14±4.26 cm). The monthly variation indicated  
191 that the highest values were observed in the dry season, during February (Layo),  
192 during August (Anyama II) then during September (Azaguié, Anyama I and Banco).  
193 The maximum average values of nitrite were recorded in Layo station. The  
194 temporal variation indicated that the maximum values were obtained in the dry  
195 season during March (Layo, Banco, Azaguié and Anyama II) and in the rainy  
196 season during November (Anyama I). The average values of ammonium oscillated  
197 between 0.12±0.16 mg/l (Anyama II) and (0.31±0.36mg/l (Banco). The great values  
198 of this parameter were recorded in the dry season during January (Banco) and  
199 September (Layo) then in the rainy season during November (Azaguié, Anyama I  
200 and Anyama II). The content phosphorus varied from 3.16±7.94 mg/l (Anyama I) to

5.56±8.35 mg/l (Layo). Overall, the highest values were obtained during November (Layo), October (Banco), June (Azaguié) and December (Anyama I). On the other hand in Anyama II station, the average was high in the rainy season during December.

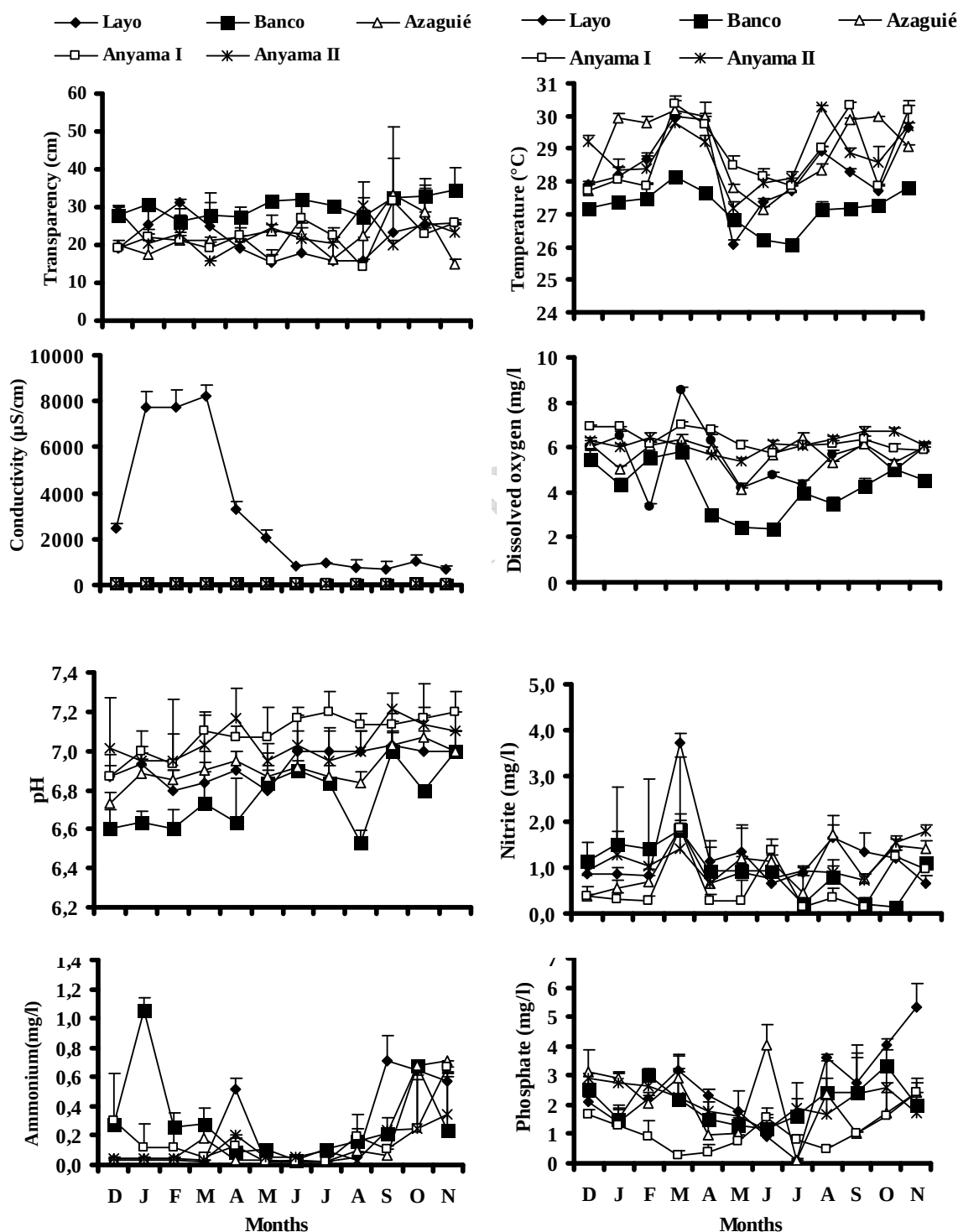


Fig. 2. Temporal variation of environmental variables in the different stations.



In Table 1 the list and dominance of the benthic insect species collected in December 2007 and November 2008 is reported. A total of 31 taxa belonging to 18 families and 7 orders were identified in the present study. The orders inventoried were Ephemeroptera, Odonata, Hemiptera, Megaloptera, Coleoptera, Diptera and Trichoptera. Diptera was the most diverse group with 14 taxa, while Megaloptera was the less diverse with 1 taxon (Table 1). In all stations, the insect populations were dominated by Diptera. The family Chironomidae occurred the highest number of taxa (11 taxa). Diptera dominated in term of abundance the settlement in all stations. *Chironomus imicola* (Do=46.13%) and *Nilodorum fractilobus* (Do=40.85%) were the dominant taxa in Layo station. In Banco station, *Stictochironomus* sp. (Do=51.93%) and *Tanypus fuscus* (Do=12.19%) dominated aquatic insect population. *Tanypus fuscus* (Do=40.08%) and *Nilodorum fractilobus* (Do=25.38%) recorded the most important abundance in Azaguié station. In Anyama I station, *Stictochironomus* sp. (Do=38.78%) and *Tanypus fuscus* (Do=30.75%) were the most abundant taxa while, *Tanypus fuscus* (Do=30.15%), *Ceratopogon* sp. (Do=17.24%) and *Chironomus imicola* (Do=15.87%) were abundantly collected in Anyama II station (Table 1).

Among the 31 taxa inventoried, some had a wide ecological valence. They were recorded at least in 4 stations. These were *Tanypus fuscus*, *Nilodorum fractilobus*, *Brachythemis* sp. and *Chironomus imicola*. In the other hand, others were very infrequent. They were highly localized. They have been collected in more than two stations. These taxa were *Macrolea* sp., *Stenochironomus* sp., *Protomacronema* sp., *Cryptochironomus* sp., *Corydalidae*, *Hydrochara ricketsi*, *Hydrometra* sp., *Laccophilus vermiculosus*, *Valleriola* sp., *Povilla adusta*, *Cricotopus kisanuensis*, *Tabanus* sp., *Ablabesmyia dusoleili*, *Pantala flavescens*, *Orthetrum* sp., *Ecnomus* sp., *Ictinogomphus* sp. and *Dipseudopsis capensis*.

**Table 1. List and dominance (Do) of benthic insects identified in the different stations**

La= Layo; Ba=Banco; Az= Azaguié; An I= Anyama I; An II= Anyama II

| Taxa                      | Stations        |              |              |                |                 |
|---------------------------|-----------------|--------------|--------------|----------------|-----------------|
|                           | Ly<br>Do<br>(%) | Bc<br>Do (%) | Az<br>Do (%) | An I<br>Do (%) | An II<br>Do (%) |
| <b>Ephemeroptera</b>      |                 |              |              |                |                 |
| Caenidae                  |                 |              |              |                |                 |
| <i>Caenis</i> sp.         |                 |              | 0.15         | 2.33           | 0.47            |
| Polymitarcyidae           |                 |              |              |                |                 |
| <i>Povilla adusta</i>     |                 | 0.59         | 0.04         | 0.07           | 0.21            |
| <b>Odonata</b>            |                 |              |              |                |                 |
| Gomphidae                 |                 |              |              |                |                 |
| <i>Ictinogomphus</i> sp.  |                 |              |              | 0.55           |                 |
| Libellulidae              |                 |              |              |                |                 |
| <i>Orthetrum</i> sp.      |                 |              | 0.04         | 0.34           |                 |
| <i>Libellula</i> sp.      |                 | 0.21         | 0.07         | 0.21           | 0.37            |
| <i>Pantala flavescens</i> |                 |              | 0.04         |                |                 |
| <i>Brachythemis</i> sp.   | 10.56           | 0.70         | 1.15         | 1.44           | 0.79            |
| <b>Hemiptera</b>          |                 |              |              |                |                 |
| Hydrometridae             |                 |              |              |                |                 |
| <i>Hydrometra</i> sp.     |                 |              |              | 0.07           |                 |
| Leptopodidae              |                 |              |              |                |                 |
| <i>Valleriola</i> sp.     |                 |              |              | 0.07           |                 |
| <b>Megaloptera</b>        |                 |              |              |                |                 |
| Corydalidae               |                 | 0.05         |              |                |                 |

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**Table 1. Extended**

| Taxa                            | Stations        |              |              |                |                    |
|---------------------------------|-----------------|--------------|--------------|----------------|--------------------|
|                                 | Ly<br>Do<br>(%) | Bc<br>Do (%) | Az<br>Do (%) | An I<br>Do (%) | An II<br>Do<br>(%) |
| <b>Coleoptera</b>               |                 |              |              |                |                    |
| Hydrophilidae                   |                 |              |              |                |                    |
| <i>Hydrochara ricketsi</i>      |                 |              | 0.04         |                |                    |
| Chrysomelidae                   |                 |              |              |                |                    |
| <i>Macrolea</i> sp.             |                 | 2.09         |              |                |                    |
| Dytiscidae                      |                 |              |              |                |                    |
| <i>Laccophilus vermiculosus</i> |                 |              | 0.07         |                | 0.05               |
| <b>Trichoptera</b>              |                 |              |              |                |                    |
| Ecnomidae                       |                 |              |              |                |                    |
| <i>Ecnomus</i> sp.              |                 |              |              | 0.34           |                    |
| Hydropsychidae                  |                 |              |              |                |                    |
| <i>Protomacronema</i> sp.       |                 | 0.11         |              |                |                    |
| Polycentropodidae               |                 |              |              |                |                    |
| <i>Dipseudopsis capensis</i>    |                 | 2.63         |              |                | 0.21               |
| Hydroptilidae                   |                 |              |              |                |                    |
| <i>Hydroptila</i> sp.           |                 | 0.05         |              |                |                    |
| <b>Diptera</b>                  |                 |              |              |                |                    |
| Chironomidae                    |                 |              |              |                |                    |
| <i>Ablabesmyia dusoleili</i>    |                 | 0.48         |              |                | 0.90               |
| <i>Chironomus imicola</i>       | 46.13           | 4.83         | 7.28         | 8.44           | 15.87              |
| <i>Clinotanypus claripennis</i> |                 | 3.92         | 1.55         | 2.54           | 2.32               |
| <i>Cryptochironomus</i> sp.     |                 | 0.27         | 2.48         |                |                    |
| <i>Nilodorum fractilobus</i>    | 40.85           | 4.83         | 25.38        | 1.65           | 7.06               |
| <i>Nilodorum brevipalpis</i>    |                 | 2.20         | 1.18         | 0.75           | 1.05               |
| <i>Polypedilum</i> sp.          |                 | 4.67         | 0.96         | 0.82           | 0.32               |
| <i>Stenochironomus</i> sp.      |                 | 0.16         |              | 0.07           |                    |
| <i>Stictochironomus</i> sp.     |                 | 51.93        | 10.27        | 38.78          | 16.50              |
| <i>Tanypus fuscus</i>           | 1.41            | 12.19        | 40.08        | 30.75          | 30.15              |
| <i>Cricotopus kisanuensis</i>   |                 |              |              |                | 0.42               |
| Ceratopogonidae                 |                 |              |              |                |                    |
| <i>Ceratopogon</i> sp.          | 1.06            |              | 1.92         | 3.16           | 17.24              |
| Chaoboridae                     |                 |              |              |                |                    |
| <i>Chaoborus anomalus</i>       |                 | 7.63         | 7.31         | 7.62           | 5.96               |
| Tabanidae                       |                 |              |              |                |                    |
| <i>Tabanus</i> sp.              |                 | 0.48         |              |                | 0.11               |

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This is the first report on aquatic insect in fishpond of Côte d'Ivoire, using both quantitative and qualitative data. During the sampling periods, the total number of benthic insect taxa was 31 (Table 1). Three of them (*Macrolea* sp., *Vallerioli* sp. and *Corydalidae*) were recorded for the first time in the Côte d'Ivoire aquatic ecosystems. They complete the list of insects' species from Ivorian aquatic ecosystems. Four taxa (*Tanypus fuscus*, *Nilodorum fractilobus*, *Brachythemis* sp. and *Chironomus imicola*) are common to all stations. They have a cosmopolitan character. They had wide ecological amplitude. These taxa are ecologically less demanding. Benthic insect fauna of fish farm ponds was dominated quantitatively and qualitatively by Diptera. This order is typical of many freshwater systems (Arslan et al., 2010). It represented 96.21% of total abundance of all the benthic insects collected. In addition, 87.29% of Dipterans in terms of abundance were Chironomidae. Thus further confirming the dominant position of Chironomids among Dipterans (Sharma et al., 1993). Similar result was observed by Ogbeibu (2001) in a temporary pond in southern Nigeria, by Diomandé et al. (2009) in Agnèby river (Ivory Coast) and by Foto et al. (2011) in Biyéme river (Cameroon). Kouamé et al. (2011) reported that the Chironomidae populations are almost

found to be numerically predominant, both in lotic and lentic environments, due to their tolerance of extreme conditions. Moreover, Merritt and Cummins (1996) reported that the life environmental conditions of Chironomids were more extensive than these of any other group of aquatic insects. Their wide ecological amplitude is related to their very extensive array of morphological, physiological and behavioural adaptations (Kouamé et al., 2011). Some genera of Diptera such as *Tanypus*, *Nilodorum* and *Chironomus*, were recorded in all stations. According to Arslan et al. (2010), genera *Tanypus* and *Chironomus* have worldwide distributions and commonly occur in freshwater standing systems. *Tanypus fuscus* have been reported as ecological tolerant (Florencio et al., 2009) and extensive geographical range (Çamur-Elipek et al., 2010). Our results supported this knowledge. By contrast, especially *Valleriola* sp., *Hydrometra* sp. (Hemiptera), *Hydroptila* sp. (Trichoptera) and Corydalidae (Megaloptera) were represented by only one specimen. These species were not particularly abundant during this study. According to Taylor and McPherson (2006) pond habitats may be marginal for these species. The large spatial variation in the abundance of aquatic insect between Layo and the other stations may be due to the low taxonomic richness observed in this station. This low taxonomic richness in Layo could be due to the abiotic conditions such as conductivity and nitrite which are higher in this station.

### 3.3 Density and biomass

The spatial and seasonal distribution patterns of benthic insect density show significant difference in Anyama I ( $F_{1, 180} = 6.47$ ;  $P = 0.01$ ) and in Anyama II stations ( $F_{1, 180} = 6.43$ ;  $P = 0.01$ ). The highest density was observed during the dry season in Anyama I and Anyama II (Table 2). The density ranged from  $83.33 \pm 45.93$  ind.m<sup>-2</sup> (Layo in the dry season) to  $846.91 \pm 351.20$  ind.m<sup>-2</sup> (Azaguié in the dry season). The spatial variation in biomass showed significant difference ( $F_{4, 180} = 6.65$ ;  $P = 0.00$ ) between the stations (Table 2). Biomass was higher in Azaguié ( $3.38 \pm 1.33$  mg.m<sup>-2</sup>) and lower in Layo ( $0.89 \pm 0.75$  mg.m<sup>-2</sup>). The seasonal distribution patterns of benthic insect biomass show significant difference in Anyama I ( $F_{1, 180} = 6.47$ ;  $P = 0.01$ ) and in Anyama II stations ( $F_{1, 180} = 6.43$ ;  $P = 0.01$ ). The highest biomass was observed during the dry season in Anyama I and Anyama II (Table 2). In the other hand, biomass ranged from  $0.91 \pm 0.84$  mg.m<sup>-2</sup> (Layo in the dry season) to  $3.56 \pm 4.50$  mg.m<sup>-2</sup> (Azaguié in the rainy season) (Table 2).

In this study, it was shown that benthic insect density was significantly different between both stations and seasons. The overall density of benthic insect varied spatially and temporary in response to environmental variables. The overriding influence of conductivity in the distribution and abundance of benthic insect fauna can explain the significantly lower density in Layo. Concerning the temporal variation, higher densities of benthic insects were recorded during the dry season in Anyama I and Anyama II stations and during the rainy season in Layo, Banco and Azaguié stations. This situation would be due to the proliferation of certain species during respective seasons in the various stations. Similar results were reported by Ogbeibu (2001). According to this author, the varied ecological requirements of individual taxa affected their spatial distribution and abundance in a temporary pond in southern Nigeria.

**Table 2. Seasonal variation of abundance, density, biomass, Shannon-Weaver diversity, Simpson and evenness indexes of aquatic insects in the among stations (mean  $\pm$  (SD)).**

| Parameters                     | Stations |                               |                               |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
|--------------------------------|----------|-------------------------------|-------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                                | Layo     |                               | Banco                         |                                 | Azaguié                         |                                 | Anyama I                        |                                 | Anyama II                       |                                 |                                 |
|                                | Seasons  | DS                            | RS                            | DS                              | RS                              | DS                              | RS                              | DS                              | RS                              | DS                              | RS                              |
| Density (ind.m <sup>-2</sup> ) |          | 83.33 <sup>a</sup><br>(45.93) | 91.97 <sup>a</sup><br>(48.77) | 570.98 <sup>a</sup><br>(352.48) | 579.01 <sup>a</sup><br>(520.66) | 824.07 <sup>a</sup><br>(351.20) | 846.91 <sup>a</sup><br>(782.76) | 606.17 <sup>b</sup><br>(487.47) | 292.59 <sup>a</sup><br>(189.44) | 714.19 <sup>b</sup><br>(402.44) | 456.79 <sup>a</sup><br>(153.24) |
| Biomass (mg.m <sup>-2</sup> )  |          | 0.91 <sup>a</sup><br>(0.84)   | 0.87 <sup>a</sup><br>(0.67)   | 2.17 <sup>a</sup><br>(1.21)     | 1.77 <sup>a</sup><br>(1.76)     | 3.20 <sup>a</sup><br>(1.56)     | 3.56 <sup>a</sup><br>(4.50)     | 3.42 <sup>b</sup><br>(2.94)     | 1.22 <sup>a</sup><br>(1.15)     | 2.61 <sup>b</sup><br>(1.34)     | 1.67 <sup>a</sup><br>(0.73)     |
| Simpson index                  |          | 0.58 <sup>a</sup><br>(0.22)   | 0.65 <sup>a</sup><br>(0.21)   | 0.33 <sup>a</sup><br>(0.17)     | 0.39 <sup>a</sup><br>(0.16)     | 0.30 <sup>a</sup><br>(0.10)     | 0.40 <sup>b</sup><br>(0.14)     | 0.38 <sup>a</sup><br>(0.15)     | 0.44 <sup>a</sup><br>(0.17)     | 0.28 <sup>a</sup><br>(0.08)     | 0.27 <sup>a</sup><br>(0.16)     |
| Shannon- Weaver index          |          | 0.95 <sup>a</sup><br>(0.54)   | 0.77 <sup>a</sup><br>(0.50)   | 2.03 <sup>a</sup><br>(0.60)     | 1.74 <sup>a</sup><br>(0.53)     | 2.09 <sup>b</sup><br>(0.47)     | 1.69 <sup>a</sup><br>(0.44)     | 1.78 <sup>a</sup><br>(0.57)     | 1.52 <sup>a</sup><br>(0.60)     | 2.08 <sup>a</sup><br>(0.42)     | 2.17 <sup>a</sup><br>(0.56)     |
| Evenness                       |          | 0.71 <sup>a</sup><br>(0.35)   | 0.65 <sup>a</sup><br>(0.37)   | 0.77 <sup>a</sup><br>(0.16)     | 0.74 <sup>a</sup><br>(0.18)     | 0.77 <sup>a</sup><br>(0.11)     | 0.72 <sup>a</sup><br>(0.17)     | 0.74 <sup>a</sup><br>(0.13)     | 0.76 <sup>a</sup><br>(0.14)     | 0.82 <sup>a</sup><br>(0.09)     | 0.84 <sup>a</sup><br>(0.13)     |

s in the same row show differences among seasons (p<0.05).

a, b,  
letter

### 3.4 Diversity and similarity indices

**Simpson index presented** a significant difference between the stations ( $F_{4, 180}=20.74$ ;  $P=0.00$ ). The highest and the lowest values of Simpson index were observed respectively in Layo and Anyama II (Table 2). Seasonal variation in Simpson index indicated that this index was similar in all stations except Azaguié where the **highest value** was observed in the rainy season (Table 2). Significant difference in Shannon-Weaver diversity index were observed among the stations ( $F_{4, 180}=29.80$ ;  $P=0.00$ ). Considering the whole benthic assemblage, the highest and the lowest values of **Simpson index** were observed respectively in Layo and Anyama II (Table 2). Seasonal variation in Shannon-Weaver diversity index indicated that this index was not significantly different between seasons except Azaguié where the highest index was observed in the dry season. The Evenness followed a similar pattern. The Evenness was significantly different among the stations ( $F_{4, 180}=2.42$ ;  $P=0.04$ ). The lowest value of Evenness was observed in Layo compared to the index value in Anyama II. On the other hand, no seasonal variation in Evenness was **observed**.

The Renkonen similarity index (PS) indicated that there is an important similarity between Anyama I and Anyama II ( $PS=71.00$ ) while the Sorensen similarity index showed that Azaguié and Anyama II were strongly similar ( $QS=77.77$ ) (Table 3). These indices revealed that minimum similarity was between Layo and the others stations.

**Table 3. Similarity indices of benthic insect's communities recorded in the different station**

| Matrix of similarity measure |            | Layo                               | Banco | Azaguié | Anyamal | Anyamall |
|------------------------------|------------|------------------------------------|-------|---------|---------|----------|
|                              |            | Sorensen similarity index (QS) (%) |       |         |         |          |
| Layo                         |            |                                    | 33.33 | 43.47   | 41.66   | 43.47    |
| Banco                        | Renkonen   | 11.77                              |       | 64.86   | 63.15   | 75.67    |
| Azaguié                      | similarity | 36.26                              | 44.21 |         | 75.67   | 77.77    |
| Anyamal                      | index      | 13.39                              | 70.49 | 63.15   |         | 70.27    |
| Anyamall                     | (PS) (%)   | 26.28                              | 50.13 | 66.61   | 71.00   |          |

The Simpson index is very sensitive to the distribution of individuals among species. The high value of this index expresses a poor organization of the ecological system and match according to environmental conditions favorable for the installation of many species represented by a few individuals (Dajoz, 1982). Shannon-Weaver diversity index is high when the taxonomic richness is important and the distribution of individuals among taxa is balanced (Maqboul et al., 2001). Our result showed that Anyama II station recorded the highest value of **Shannon-Weaver diversity index and the lowest value of Simpson index**. This station has a well diversified population where many taxa are represented **digitally**. Benthic **insect's community** of ponds in this station **was** in harmony. In addition, the highest values of Shannon-Weaver diversity index and evenness recorded in Anyama II could also be **due to the good distribution of taxa** in this station. The lowest values were recorded in the stations of Azaguié, Anyama I, Banco and Layo. This situation could be due to the presence of an unbalanced community represented by a small number of very abundant taxa relative to the other (Maqboul et al., 2001). According to Amanieu and Lasserre (1982) and Dajoz (2000), **more the** evenness is close to 1, **more the** settlement is balanced and stable. In contrary, an evenness closed to 0 **translated an** imbalance of the settlement following the multiplication of a limited number of species due to natural or **anthropic** factor. The settlement structure of these stations is marked by a small number of species that dominate quantitatively, which could make the settlement of those disturbed habitats (Blondel, 1979). Indeed, *Nilodorum fractilobus* and *Chironomus imicola* were abundantly recorded in Layo, *Stictochironomus* sp. was the most important in Banco, *Tanytus fuscus* dominated quantitatively the settlement in Azaguié then in Anyama I, *Tanytus fuscus* and *Stictochironomus* sp. were mainly represented. These taxa

dominated quantitatively the other. The Shannon-Weaver index and evenness values were important in the dry season while the Simpson index followed a contrast pattern in this season too in most of the stations. These results indicate that ponds ecosystems presented fewer disturbances during the rainy season in Anyama II and during the dry season in the other stations.

The Sorensen and Renkonen similarity indices calculated between Layo and the others stations were low. This observation might be due to the low specie richness harvested in this station. In the other hand, the insect population identified in the others stations had an important similarity. The Sorensen and Renkonen similarity indices calculated confirmed this result. Indeed, the recorded values were significant; they fluctuated between 63.15% and 77.77% for Sorensen similarity index. Concerning the Renkonen similarity index, 2/3 of the observed values ranged from 63.15% to 71.00%. The taxonomic composition of the different stations could be so homogeneous.

### 3.1.5 Relationships between environmental variables and benthic insect communities

The Pearson correlation analysis between environmental variables and density and biomass of aquatic insect showed that both density and biomass were strongly correlated with dissolved oxygen. In addition, density correlated negatively with ammonium and positively with both temperature and mud (Table 4).

The results of redundancy analysis revealed that the relationships between insects' taxa and their habitat conditions follow mainly the first two axes (Fig. 3). These two axes accounted for 89.7% of the total variance. Following the axis I, are negatively correlated electrical conductivity, nitrite and the sand. The mud and transparency are positively correlated to this axis. Temperature, pH, and dissolved oxygen are negatively correlated to the axis II. Ammonium and phosphorus are positively correlated to this axis. The redundancy analysis defines four taxonomic groups. The first one was composed by *Tanytus fuscus*, *Nilodorum brevipalpis*, *Stictochironomus* sp., *Clinotanytus claripennis* and *Chaoborus anomalus*. These taxa are mainly present in Anyama I station which was characterized by high content of clay. The second group including *Caenis* sp. and *Ceratopogon* sp. are mainly observed in Anyama II and Azaguié stations which were characterized by high values of pH, temperature and dissolved oxygen. *Povilla adusta*, *Macrolea* sp., *Dipseudopsis capensis*, *Ablabesmyia dusoleili*, *Cryptochironomus* sp. and *Polypedilum* sp. were essentially recorded in Banco where the values of transparency and ammonium are quite high. This station was also characterized by a substrate dominated by mud. The fourth group was constituted by *Nilodorum fractilobus*, *Brachythemis* sp. and *Chironomus imicola*. These taxa are mainly present in Layo where high levels of conductivity, nitrite and phosphorus were noted. The substrate of Layo is mostly composed by sand.

**Table 4. Pearson correlation between environmental variables and density and biomass of aquatic insects.**

| Environmental variables | Density | Biomass |
|-------------------------|---------|---------|
| Transparency            | 0.0649  | -0.0935 |
| Temperature             | 0.1720* | 0.1238  |
| Conductivity            | 0.0800  | -0.0343 |
| Dissolved oxygen        | 0.3004* | 0.2563* |
| pH                      | 0.0791  | 0.0212  |
| Mud                     | 0.1569* | 0.0509  |
| Sand                    | -0.1353 | -0.0644 |
| Clay                    | 0.0054  | 0.1371  |
| Nitrite                 | -0.0353 | -0.0403 |

|            |          |         |
|------------|----------|---------|
| Ammonium   | -0.1852* | -0.0996 |
| Phosphorus | -0.0997  | -0.1311 |

\* indicates significant difference (P<0.05)

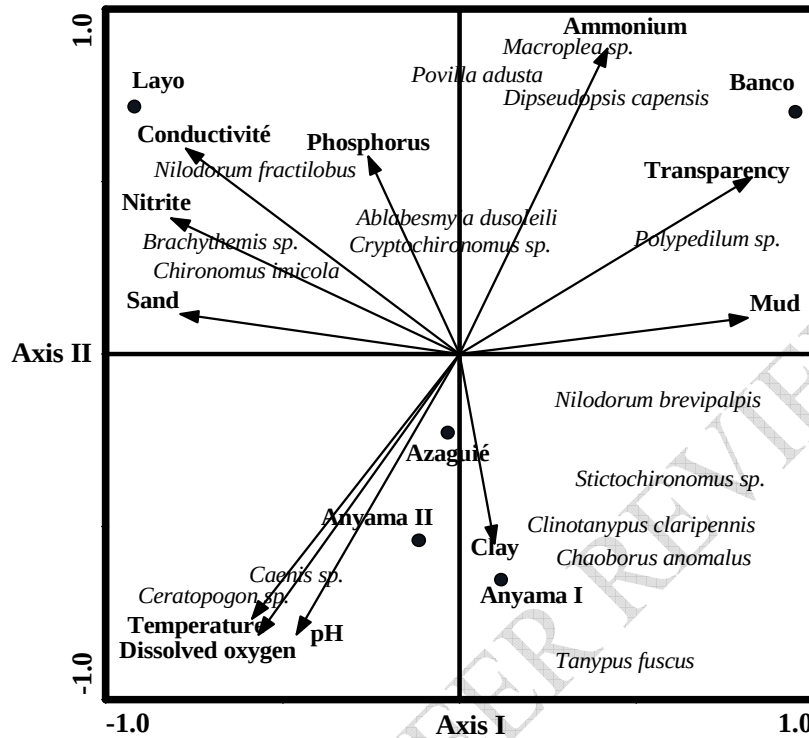


Fig.3. Canonical correspondence analysis showing correlation between principal taxa recorded.

The pattern distribution according to environmental variables indicates that *Ceratopogon* sp. and *Caenis* sp., were associated to high value of pH, temperature, and dissolved oxygen. In southern Ivory Coast, Edia (2008) found significant relationships between species composition and pH, temperature, and dissolved oxygen in the Soumié, Ehania, Tanoé and Eholié rivers. Similar result was observed by Diomandé *et al.* (2009) in Bia River (southern Ivory Coast). In a temporary pond in Okomu Forest Reserve, southern Nigeria, Ogbeibu (2001) observed a significant positive correlation between density and water temperature. According to Ross *et al.* (1982), temperature is one of the most important environmental factors controlling aquatic insect density. In addition, high water temperatures might accelerate the feeding activity of benthic predators *Brachythemis* sp., *Nilodorum fractilobus* and *Chironomus imicola*. Likewise positive correlation was observed between both *Ablabesmyia dusoleili* and *Cryptochironomus* sp. and phosphorus. *Macrolea* sp. and *Dipseudopsis capensis* were positively correlated to ammonium.

#### 4. CONCLUSION

The present study reported 31 benthic insect taxa in the different stations. Three of these taxa were recorded for the first time in Côte d'Ivoire aquatic ecosystem. Diptera was the most diversified and numerically the most abundant group. The family Chironomidae was qualitatively and quantitatively the most important among Diptera. The insect community in the different stations is quite diverse

and stable except Layo. This community has an important similarity between Anyama I, Anyama II, Azaguié and Banco. This study has shown that the variation of density of benthic insects in the fishponds was influenced by certain environmental parameters such as temperature, conductivity and dissolved oxygen. Aquaculture in fishponds can be balanced with conservation of aquatic insect diversity and density through management methods that preserve the aquatic habitats and resources for **foods** (Çamur-Elipek et al., 2010).

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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