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Effect of three exogenous foods used in *Oreochromis niloticus* (Linné, 1758) foods on the diversity and structure of aquatic entomofauna stands in Blondey fishponds (Ivory Coast; West Africa)

Idrissa Adama Camara[1*], Nangounon Soro[2], Kouadio Kouakou Norbert[3], Doumbia Lacina[4], Ouattara Allassane[5], Dramane Diomande[6]

[1-2, 4-6] Laboratoire d'Environnement et de Biologie Aquatique, UFR-Sciences et Gestion de l'Environnement, Université Nangui Abrogoua, 02 BP 801, Abidjan, Côte d'Ivoire

[3] Department of Engineering, Agronomy and Forestry, University of Man, BP 20 Man, Côte d'Ivoire

Abstract

The insect class strongly contributes to the nutrition of fish in ponds. However, the use of exogenous foods in fish farming often modify the physicochemical quality of water in fish ponds. Thus, the diversity and structure of the insect class can be disrupted. This study aims to evaluate the effect of three exogenous foods used in *Oreochromis niloticus* foodsing on the diversity and structure of the insect community in Blondey fish ponds. Those foods formulated solely with animal by-products were tested in juvenile and adult stages. Thus, seven fishponds whose four (E1, E2, E3, E4) at juvenile stage and three (E7, E8, E9) at adult stage were selected. Among them, E2, E3, E4, E8 received exogenous food while E1 and E9 stocked with no exogenous food were used as witness. Insects samples were taken monthly using artificial substrats, from october 2016 to June 2017. A total of 100 insects taxa divided into seven orders dominated by Odonata, Coleoptera and Diptera were obtained. The taxonomic richness was high in fishponds that received exogenous food s and low in those without exogenous foods during the two stages (adulte and juvenile). The fishponds E4 and E8 that received housefly maggot meal registered the highest taxonomic richness. Concerning water quality of the fishponds that received exogenous foods, it oscillated between poor and very poor. The Focused Principal Component Analysis (FPCA) indicates that dissolved oxygen, pH, transparency and phosphate influence significantly the abundance of Setodes sp., *Nilodorum brevibucca* and *Nilodorum brevipalpis* in Blondey fishponds.

Keywords: fishponds, exogenous foods, aquatic entomofauna, blondey

1. Introduction

In the underdeveloped countries, the fight against food insecurity requires the development of several agricultural activities including fish farming (Efole-Ewoukem, 2011) [11]. But the promotion of this culture leads the actors to use exogenous food for the foodsing of the fish. However, beyond its expensive costs because of the protein source that is mainly fishmeal (Siddhuraju & Becker 2003, Verreth *et al*., 2007) [26, 30], these external food inputs, while promoting the growth of fish production, are most often at the base of increased fertilization of livestock structures (Pouomogne *et al*., 1998) [19]. However, the high enrichment of these nutrient media could lead to eutrophication, which is synonymous with an imbalance in the presence of wildlife in these artificial hydrosystems (Sevrin-Reyssac, 1985) [25]. However, young *Oreochromis niloticus* preferentially consume insect larvae (El-Sayed, 2006) [13]. In addition, insects are unquestionably indicators generally considered the most relevant for characterizing aquatic ecosystems, and in particular ponds. According to Schneider (2007), this class contains bio-indicator species of water quality. It is the most diverse group with more than 70% of the taxonomic richness in freshwater hydrosystems (Bameul, 2008) [2].

In Ivory Coast, much work has been done on the diversity and structure of insects in fish ponds (Yapo *et al*., 2007; 2012; 2013; 2014; 2015; 2016; 2017 & Edia, 2013) [31, 9]. However, no study has examined the ecological functioning of fish ponds based on insect communities. The overall objective of this work is to evaluate the effect of exogenous fish foods *Oreochromis niloticus* on the diversity and insect structure of Blondey fishponds in order to determine the ecological functioning of these hydrosystems. Specifically, it is (i) to determine the effect of exogenous foods on the physico-chemistry of the waters of Blondey's fish ponds; (ii) to determine the effect of exogenous foods on the diversity and structure of insect communities at the Blondey Fish Farm and (iii) to identify the abiotic variables that influence the distribution of the most abundant insect taxa.

2.1 Material and methods

2.1. Study area and sampling sites

This study was undertaken in the piscicultural farm of Blondey located in South Ivory Coast at 25 km to Abidjan (Economic capital). This farm has 28 ponds and was used for Nile tilapia (*Oreochromis niloticus*) culture. All the ponds were fed by a man-made lake nearby. This lake was fed in rainy season by running water from palm plantation surrounding the lake. Among the ponds, seven (E1, E2, E3, E4, E7, E8, E9) with average depth of 0.8 m were used (Fig. 1). Four of these ponds (E1, E2, E3, E4) with an area of 800 m² (20 × 40 m) were used for the juvenile stage and three ponds (E7, E8 and E9) with an area of 600 m² (20 × 30 m) in the adult stage due to the food earthworm removal as exogenous food. The fishponds E2 and E7 received fishmeal as exogenous food, E3 earthworm meal and E4 and E8 received housefly maggot meal (Table 1). The fishponds E1 and E9 didn't received exogenous foods.

Table 1: Characteristics of the study fishponds in the fish farm of Blondey (Ivory Coast, West Africa).

Characters	Ponds						
	E1	E2	E3	E4	E7	E8	E9
Geographical positions	5°35'25 N 4°05'25 W	5°35'25 N 4°05'23 W	5°35'26 N 4°05'23 W	5°35'26 N 4°05'23 W	5°35'25 N 4°05'26 W	5°35'26 N 4°05'24 W	5°35'25 N 4°05'27 W
Ponds area (m²)	800	800	800	800	600	600	600
Fishmeal	no	yes	no	no	yes	no	no
Housefly maggot meal	no	no	no	yes	no	yes	no
Earthworm meal	no	no	yes	no	no	on	no

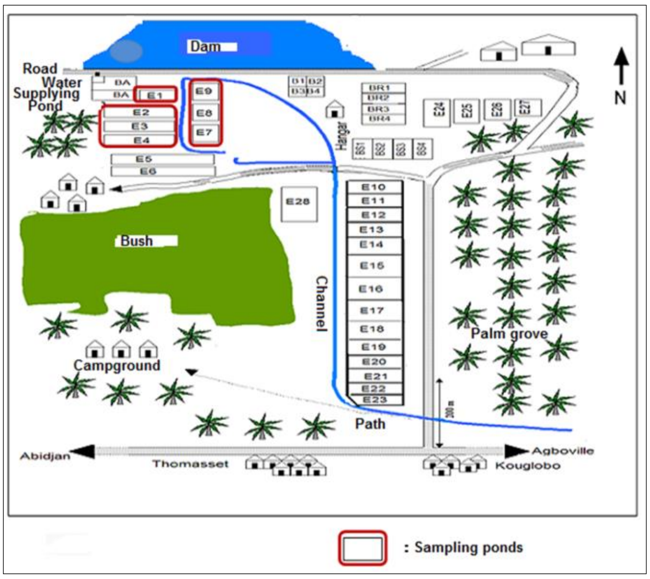

Fig 1: Location of study area (E1, E2, E3, E4: ponds used for the juvenile stage; E7, E8, E9: ponds used for the adult stage) in Blondey fish farm (Ivory Coast)

2.2. Data collection

The insect stands sampling were undertaken monthly during two periods. The first period: from October 2016 to December 2016 corresponding to the juvenile stage in the selected fishponds (E1, E2, E3, E4) and the second period: from January 2017 to June 2017 corresponding to the adult stage in the selected fishpond (E7, E8, E9). Sampling was done using artificial substrats (stones and branchs) in plastic baskets (0.20 m in diameter, 0.14 m of height and 0.005 m aperture size). In each selected fishpond, four baskets were immersed by the nylon rope and the samples were taken by removing monthly and rinsing them through the water pond into a sieve of 1 mm aperture size. The samples retained on the mesh were immediatly fixed in 70 % alcohol. In the laboratory, organisms collected were sorted and identified under a binocular magnifying glass (Olympus SZ 40) to the lowest possible taxonomic level by using the keys of Dejoux *et al.* (1981) [8]; Day *et al.* (2002; 2003) [4]; De Moor *et al.* (2003 a, b) [4]; Stals & De Moor (2007) [5]; Tachet *et al.* (2010) [29].

At each sampling period, before insects sampling, five environmental variables (transparency, temperature, pH, dissolved oxygen and conductivity) were measured using a multiparameter digital meter except transparency which was determinate using a 0.20 m diameter Secchi disk. For nutrients (nitrates and soluble reactive phosphorus), subsamples of 500 mL were collected and refrigerated for later analysis following the spectrometric method (AFNOR, 2005) [1].

2.3. Data analysis

Insects diversity and structure were described using taxonomic composition, rarefied taxonomic, Shannon-Weaver diversity index (H') (Quinn & Hickey, 1990), Pielou Evenness index (E) (Pielou, 1969), frequency of occurrence (FO) and abundance. Shannon-Weaver diversity index was used to assess taxa diversity of insect. Evenness was used to show the organization of the structure, regardless of species richness. Calculations were performed using the vegan package (Oksanen *et al.*, 2013) [18] for the R 3.0.2 freeware (R Core Team, 2013). FO is the percentage of samples in which each taxon occurred. It was calculated to classify the insects according to Dajoz (2000). Before performing the comparison test, the normality of data was checked by Shapiro test. Variations in environmental variables and biotic index were determined using the Mann-Whitney *U*-test. A significance level 0.05 was considered.

The ecological quality of fishponds water was assessed by using the Family Biotic Index (FBI) (Hilsenhoff, 1988) [16]. The formula for calculating the Family Biotic Index is:

$$FBI = \sum \frac{ni \times ai}{N}$$

Where ni is the number of individuals of i^{th} taxon; ai is the tolerance value of that taxon and N is the sum of individual numbers in all the families making up the sample. In the FBI, increasingly high score indicates lower water quality (Table 2). The higher the score is the more the habitat is likely to be affected by stress. The Index value (ai) used the equation are related to how well the family can tolerate organic pollutants, increased nutrient and sediment loads and dissolved oxygen (DO) limitations (Mandaville, 2002) [117].

The distribution of aquatic insects in the sampling fishponds were determined by the Focused Principal Component Analysis (FPCA) using package "psy" of R version 3.0.2 software.

3. Results

3.1. Environmental characteristics of fishponds

The variations of environmental variables among fishponds at the juvenile and adult stages are given respectively in table 3 and 3. At the juvenile stage, the minimal value of water temperature was obtained (26°C) in E1 and the maximal (29°C) in E4. The dissolved oxygen ranged between 2.4 mg/L (E2, E3) and 5.84 mg/L (E1). The low values of pH (4.4) was registered in the fishponds E2 and E3 while the high value (7.84) was observed in the fishpond E1. Concerning electric conductivity, it varied from 43.8 µS/cm (E1) to 61.9 µS/cm (E2). The transparency values were ranged from 10 cm in E2, E3 to 48 cm in E1. The low values of nitrate (0.29 mg/L) and phosphate (0.211 mg/L) were registered in E1 while the high values (0.62 mg/L and 0.63 mg/L) of these parameters were observed respectively in E2 and E3 (Table 3). There were no significant variations of water temperature, pH and ammonia between fishponds water during this period (Mann-Whitney test, $p > 0.05$). However, dissolved oxygen and transparency were significantly higher in fishpond E1 than fishponds E2, E3, E4 while electric conductivity, nitrate and phosphate were significantly lower in fishpond E1 than fishponds E2, E3, E4 (Mann-Whitney test, $p < 0.05$).

At the adult stage, water temperature oscillated between

25.6°C (E8) and 29°C (E9). The dissolved oxygen ranged from 2.3 mg/L (E7) to 6.08 mg/L (E9). Concerning pH, the values varied from 4.3 (E7) to 8.08 (E9). Electric conductivity values ranged from 31.5 µS/cm (E9) to 60.15 µS/cm (E8). The minimal value of transparency (9 cm) was obtained in E7 while the maximal value (46 cm) was registered in E9. The nutrients such us nitrate and phosphate were registered these minimal values (0.26 mg/L and 0.209 mg/L) in E9 and the maximum values (0.58 mg/L and 0.52 mg/L) in E7 and E8 (Table 4).
The values of water temperature, pH and ammonia showed no significant variations between fishponds water (Mann-Whitney test, $p > 0.05$) during this period. However, dissolved oxygen and transparency were significantly lower in fishponds E7 and E8 than fishpond E9 while electric conductivity, nitrate and phosphate were significantly higher in fishponds E7 and E8 than fishpond E9 (Mann-Whitney test, $p < 0.05$).

3.2. Composition, occurrence, diversity and abundance

A total of 100 taxa of aquatic insecta belonging to seven orders (Ephemeroptera, Trichoptera, Coleoptera, Heteroptera, Odonata, Diptera, Lepidoptera) and 40 families were identified in the selected fishponds of Blondey (Table 5). The Order of Odonata is the most diverse with 25% of taxonomic richness. It is followed by Coleoptera (22 %), Diptera (21 %), Heteroptera (18 %), Ephemeroptera (8 %), Trichoptera (4 %) and Lepidoptera (2 %) (Fig. 2). Of all the taxa collected on the Blondey fish farm, only *Nilodorum brevibucca* and *Cryptochironomus* sp. (Chironomidae) were obtained at all fishponds. The high numbers of taxa were collected at fishponds E2, E4, E7, E8 with respectively 38, 42, 43, 46 taxa and the low numbers were registered at fishponds E1 (23 taxa), E3 (21 taxa), E9 (24 taxa). At the juvenile stage, 51 taxa were recorded while 88 taxa were observed at the adult stage (Table 5).

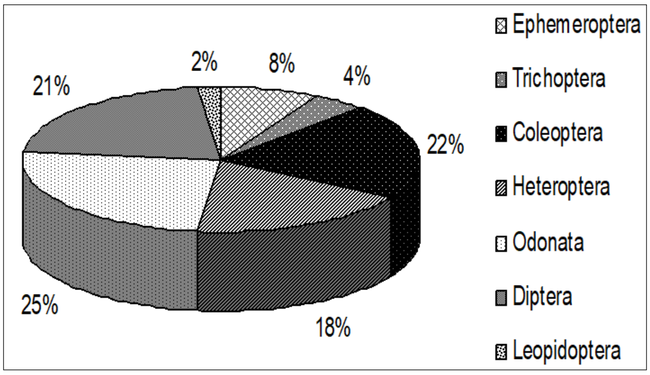

Fig 2: Global proportion in terms of taxa of the six orders of insects collected on the Blondey fish farm (Ivory Coast)

At the juvenile stage, ten taxa (*Povilla adusta, Povilla* sp., *Setodes* sp., *Parasetodes* sp., *Phyllomacromia* sp., *Ictinogomphus* sp., *Zygonyx torrida, Trithemis verneri, Parazyxoma flavicans, Nilodorum brevibucca.*) were very frequent (FO > 50%). while at the adult stage, 25 taxa were very frequent. Among these taxa, *Nilodorum brevibucca* was only commonest taxa found at all breeding stages (Table 5). In short, the rare taxa occurrence (FO < 25%) dominated (49 %) the taxonomic richness, followed by frequent (25% ≤ FO ≥ 50%) taxa (36 %) and very frequent taxa (15 %) (Fig. 3).

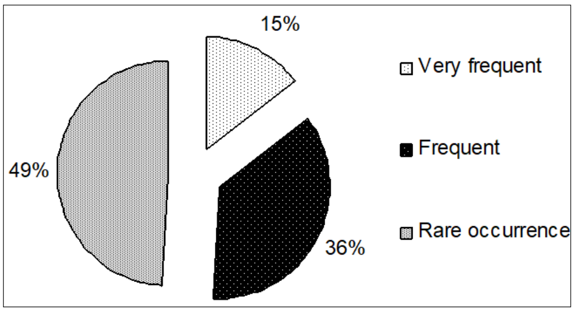

Fig 3: Global proportion in terms of taxa of the three groups of occurrences of insects collected on the Blondey fish farm (Ivory Coast)

In the fishponds E1 and E9 the abundance of Trichoptera ranges from 25% to 45% respectively in the juvenile and adult stages. In the fishponds that received exogenous foods, their abundance ranged from 1.25% (E3) to 15% (E4) at juvenile stage. Conversely the order of Diptera was the most abundant with more than 80 % of individuals during the two periods. The others order of insecta class collected were less represented (Fig. 4). The orders of Trichoptera and Diptera were most dominated respectively by the families of Leptoceridae and Chironomidae. The family of Leptoceridae was dominated by *Setodes* sp. while *Nilodorum brevibucca*, *Nilodorum brevipalpis*, *Nilodorum brevipalpis* and *Stictochironomus* sp. were most abundant in the family of Chironomidae. The family of Leptoceridae was abundant in the fishponds E1 and E9 while the family of Chironomidae was dominated in the fishponds E2, E3, E4, E7 and E8 (Fig. 5).

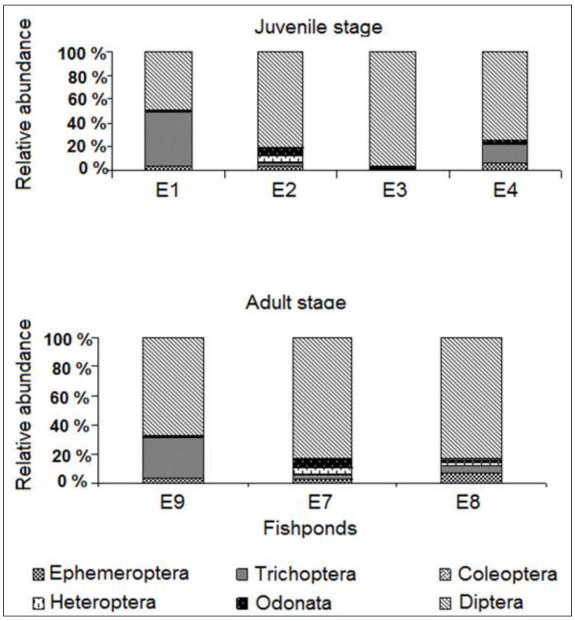

Fig 4: Proportion in terms of the number of taxa of the six orders of insects harvested during the juvenile stage and of the adult stage of *Oreochromis niloticus* in the fishponds of Blondey (Ivory Coast)

Concerning the diversity, at the juvenile stage, the minimal value of rarefied richness (5.8) was obtained in fishpond E1 while the maximal value (7.8) was registered in the fishpond E3. Shannon-Weaver index oscillated between 1.0 and 2.8 respectively in E1 and E4. The low values (0.46) and the high values (0.95) of Evenness were observed respectively in the fishponds E1 and E4 (Fig. 6). The Shannon-Weaver index and the Evenness values were significantly higher in the fishponds E2, E3, E4 than in fishpond E1 (Mann-Witney test, $p < 0.05$). The rarefied richness was not significantly different between the fishponds (Mann-Witney test, $p > 0.05$). The Evenness values were significantly different between fishponds E1, E3 and E2, E4.

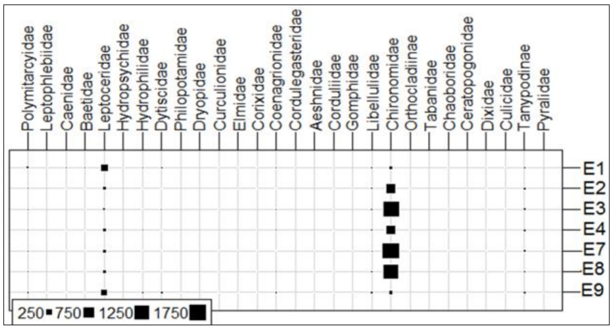

Fig 5: Abundance of different families of insecta class collected in fishponds of Blondey (Ivory Coast)

At the adult stage, the values of rarefied richness oscillated between 5.8 (E9) and 7.75 (E8). Relatively to Shannon-Weaver index, it varied from 0.172 (E9) to 2.81 (E8). Concerning the Evenness, the values oscillated between 0.62 (E9) and 0.96 (E7). The Evenness and Shannon-Weaver index values were significantly lower in the fishponds E9 and E7, E8 (Mann-Witney test, $p < 0.05$) while the rarefied richness was not significantly varied between the fishponds (Mann-Witney test, $p > 0.05$) **(**Fig. 6).

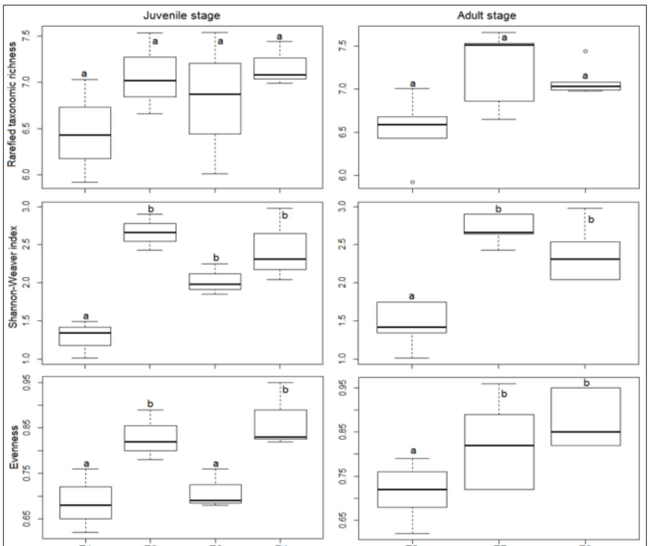

Fig 6: Box-plots showing variations in diversity index of rarefied taxonomic richness, Shannon-Weaver, evenness) between fishponds of Blondey (Ivory Coast, West Africa) (E1/E9 = fishponds without exogenous feed; E2/E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4/E8 = fishponds with housefly maggot meal) at the juvenile and adult stages of *Oreochromis niloticus*, different letters on box-plots denote significant differences between them ($P < 0.05$; Mann-Whitney test).

3.3. Characterization of fishponds using aquatic insects

The values of Hilsenhoff's Family Biotic Index (FBI) were ranged from 4.88 (E1) to 7.64 (E3) (Fig. 7). FBI values were low in the fishponds E1 (4.88) and E9 (5.10) and high (6.90 to 7.64) in the fishponds E2, E3, E4, E7 and E8.

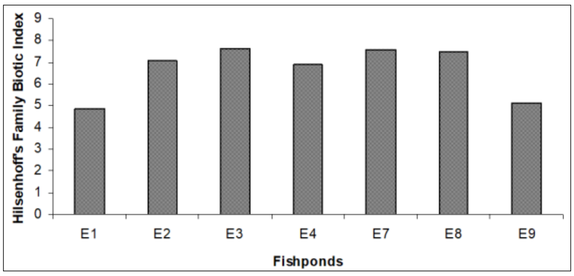

Fig 7: Variation of Hilsenhoff's Family Biotic Index of the different fishponds of Blondey (Ivory Coast)

3.4. Relationships between environmental variables and insect communities

Focused Principal Component Analysis (FPCA) was performed using environmental parameters with a focus on the most abundant taxa. Thus, the FPCA states that the taxa *Setodes* sp. is positively and significantly influenced ($P < 0.05$) by the pH, dissolved oxygen and phosphate. But this taxa is negatively correlated with temperature, transparency and conductivity. *Nilodorum brevipalpis* is significantly correlated with dissolved oxygen, pH, conductivity, phosphate and ammonium. Moreover, this taxa is negatively correlated with temperature and the transparency and positively correlated with other parameters. Relative to *Stictochironomus* sp., it is significantly correlated with dissolved oxygen, pH, conductivity, phosphate, nitrate and ammonium. This dipteran is negatively correlated with transparency and temperature and positively correlated with other parameters. As regards *Nilodorum brevibucca*, it is negatively correlated with transparency and nitrate and positively correlated with the rest of the settings. This taxa is significantly correlated with dissolved oxygen, pH, transparency and phosphate (Fig. 8).

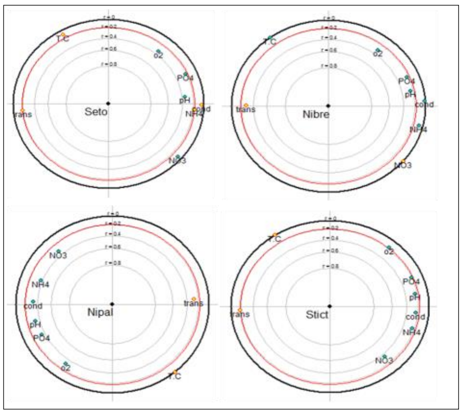

Fig 8: Graphs illustrating the results of Principal Focused Component Analysis (FPCA) based on the four abundant insecta taxa as dependent variables and the physico-chemical parameters representing the independent variables. The yellow dots correspond to the abiotic parameters negatively correlated to the abundance of the taxa while the green dots indicate those which are positively correlated with the abundance of the taxon. The points inside the circle in red represent the parameters significantly correlated ($P <0.05$) with the abundance of the taxa (Nibre = *Nilodorum brevibucca*, Nipal = *Nilodorum brevipalpis*, Stict = *Stictochironomus* sp., Seto = *Setodes* sp trans = transparency, T ° C = temperature, cond = conductivity, o2 = dissolved oxygen, pH = hydrogen potential, PO4 = phosphate, NH4 = ammonium, NO3 = nitrate).

4. Discussion

A total of 100 taxa of aquatic insecta belonging to seven orders (Ephemeroptera, Trichoptera, Coleoptera, Heteroptera, Odonata, Diptera, Lepidoptera) and 40 families were identified in the fishponds of Blondey. This high taxonomic richness would be due to the stability of these aquatic ecosystems. Indeed, Yapo *et al*. (2007; 2012; Edia, 2013) [31, 9] mentioned that artificial ponds are ecosystems that contribute to the biodiversity of aquatic insects' assemblages. According to Gee *et al*. (1997), the construction of fishponds and pools is an important mesure to compensate the loss of biodiversity. The taxonomic richness obtained in this study is higher than those observed by Edia (2013) [9] (25 taxa) in three fishponds located in the northern and by Yapo *et al*. (2017) [31] (79 taxa) in five fish farms situated in the Southern Ivory Coast. This difference in taxonomic richness was probably due to the sampling methods or sampling tools. Edia (2013) [9] collected aquatic insects in three fishponds by mean of hand net and Yapo *et al*. (2017) [31] using a hand net and a Van Veen grab. The Odonata, Coleoptera and Diptera were the most diversified orders with respectively 25 %, 22 % and 21 % of taxonomic richness. They represente together 68 % of the total taxa collected. The dominance of Diptera and Coleoptera in term of richness was obtained by Yapo *et al*. (2016) [31] in some fishponds of the southern Ivory Coast.

The high values of taxonomic richness was higher found in the fishponds that received exogenous foods than those without received. This difference in taxonomic richness would be due to the abundance of nutrients (phosphorus and nitrate) in the fishponds that received exogenous foods. Indeed, Severin-Reyssac (1985) [25] the good environmental conditions in the fishponds favour the development of naturals foods (plankton and invertebrates) of fishs. The Trichoptera were high in the fishponds without exogenous foods and low in those received exogenous foods. This result would be due to high values of dissolved oxygen registered in the fishponds without exogenous foods. The taxa of this order are useful indicators of good quality of aquatic ecosystems (Chantaramongkol *et al*., 1983; Stanic-Koštroman *et al*., 2012) [3, 28]. Moreover, the Trichoptera order was most abundant in the fishponds without exogenous foods while the Diptera were high in the fishponds that received exogenous foods. This result could be explained by the low concentration of dissolved oxygen in these fishponds. Indeed, Cheol-ki *et al*. (2006) mentioned that the taxa of Diptera are useful indicators of bad quality of aquatic ecosystems.

The values of the Shannon-Weaver index and Evenness were significantly higher in the ponds that received exogenous foods than in those without receive exogenous foods, regardless of the rearing phase. This could translate to a more diverse insects stand with the supply of exogenous foods. The evenness value was greater than or equal to 0.6 at the level of all the food treatments. This finding could also reflect a well-organized insect's population. However, these indices reveal a significant variation between the ponds receiving the exogenous foods and the control ponds. Variability of these parameters could be explained by the difference in nutrient content (nitrate and phosphate) between the two groups of stations. The results corroborated with those of Hasnaoui *et al*. (2007) [15] obtained in nursery ponds in Morocco.

FBI values ranged from 4.88 to 7.64. These values were comprised between 4.26 and 10.00. Fishponds water quality oscillated between good and very poor. The FBI of fishpond E1 was 4.88 so water quality of this fishpond was good. The FBI values of the fishponds that received exogenous foods were ranged from 6.90 to 7.64. The water quality of these fishponds oscillated between poor and very poor.

The relationships between environmental variables and insects' communities through Focused Principal Component Analysis (FPCA), indicate that *Setodes* sp., *Nilodorum brevibucca* and *Nilodorum brevipalpis* were significantly correlated with dissolved oxygen, pH, transparency and phosphate. These taxa could be used as indicators of water fishponds quality.

5. Conclusion

Concerning the biotic characterization, the insect's population analysis mentions 100 taxa distributed between seven orders Ephemeroptera, Trichoptera, Coleoptera, Heteroptera, Odonata, Diptera, Lepidoptera. Fishponds that received exogenous foods contained the highest values of taxonomic richness in contrast to the ponds that did not received the exogenous foods. Housefly maggot meal is the best exogenous food which increases the diversity and structure of insect's community. The study of hydrobiological quality of the fishponds by the biological approach (Hilsenhoff Family biotic Index) showed that water quality of the fishponds without exogenous foods was better than the water quality of the fishponds that received exogenous foods. The Focused Principal Component Analysis (FPCA) indicate that dissolved oxygen, pH, transparency and phosphate influence significantly the abundance of Setodes sp., *Nilodorum brevibucca* and *Nilodorum brevipalpis* in Blondey fishponds.

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