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Impact of fish feeding on the diversity and structure of aquatic macroinvertebrates in fishponds of Blondey (Côte d'Ivoire; West Africa).

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ABSTRACT

This study aims to assess the impact of fish feeding on the diversity and structureof aquatic macroinvertebrates in fishponds of Blondeyin Southern Côte d'Ivoire. It was conducted in three fish ponds: a Pond Without Fish (PWF), a Pond Stocking with Fishs Without artificial Feed (PSFWF) and a Pond Stocking with Fishs that receive artificial Feed (PSFF) of Blondey**.** In each pond, aquatic macroinvertebratesamplings were undertaken monthly with artificial substrat (plastic basket of 20 centimeters in diameter, 14 centimeters of height and 0.5 centimeters aperture size) from November 2015 to October 2016. Environmental variables such as transparency, temperature, pH, dissolved oxygen, oxygen redox potential andconductivity were measured *in situ.* A total of 45 taxa of aquatic macroinvertebrates belonging to three classes (Achets, Gasteropods and Insects), seven orders (Ephemeroptera, Odonata, Heteroptera, Trichoptera, Coleoptera, Diptera and Basomatophora) and 24 families were collected. Insect class dominated quantitatively and qualitatively aquatic macroinvertebrate community at each fishpond. Inside this predominated class, Odonata (12 taxa) and Diptera (9 taxa) were the most diversify. Taxa richness is higher in PWF and PSFF and lower in PSFWF. The abundance of Ephemeroptera and Trichoptera decreased respectively from ponds without fishs to ponds stocking with fishs that receive artificial feed. However, the contrary result was registered with Diptera (Chironmidae) in these same fish ponds. High value of conductivity was obtained in PSFF while high dissolved oxygen value was registered in PWF.*Melanoides tuberculata* (Gasteropoda) and Achetawere the two very frequent taxa in all the three fishponds. The Sorensen similarity index showed highest similarity (52%) between PSFWF and PSFF. Aquatic macroinvertebratescommunity structure was visualized using Canonical Correspondence Analysis to show the affinities of each species for selected environmental parameters.This study revealed that conductivity and temperature were the most dominant variables governingthree Diptera (*Nilodorum brevibucca*, *Polypedilum deletum*, *Aedes* sp.) and one Heteroptera (*Anisops sardea*) distributionin PSFF. However, the repartition of two Ephemeroptera (*Povilla adusta*, *Exeuthyplocia* sp.) and one Trichoptera (*Parasetodes* sp.) were mainly influenced byTransparency and dissolved oxygenin PWF.

Keywords: aquatic macroinvertebrates, fishponds, Impact, feeding, diversity, structure, Blondey, Côte d'Ivoire, West Africa.

1-INTRODUCTION

Fishpond ecosystems have recently been recognized as important habitats for the maintenance of biodiversity (Oertli *et al*., 2005) particularly for macrofaunabiodiversity (Apinda-Lognouo, 2007).Aquatic macroinvertebrates are generallyused in bioassessment programs for determining the ecological quality of fishpond(Moretti & Callisto, 2005; Edia, 2013;Yapo*et al*., 2017).The identificationof species and their distribution patterns providemore information for monitoring and conservingthese ecosystems.Moreover aquatic macroinvertebrates play an important role in aquatic ecosystems functioning (Dunbar *et al*., 2010). At the larval stage, they constituted the principalnutritive fauna of fish or many predatory organisms (Tachet *et al*., 2010; Broyer & Curtet, 2010).

In Côte d'Ivoire, several studies have been conducted on the distribution, taxonomic abundance and systematic of macroinvertebrates in the running waters (Edia *et al*., 2010 ; 2013 ; 2015; Kouadio, 2011 ; Camara *et al*., 2012 ; Diomandé *et al*., 2014 ; Kouamé, 2014). However, without studies of Edia (2013); Yapo *et al*. (2007; 2012; 2013;2014; 2015; 2017) on diversity and systematic of aquatic insects of fishpond, never study has been conducted on macroinvertebrates in slowing water such as fishpond ecosystem. Yet, those man made habitats play an important roles in the conservation of aquatic biodiversity (Scheffer *et al*.,2006; Yapo*et al*., 2013).Nowdays, aquatic macroinvertebrates are little know concerning ecological functionning of those ecosystems (Herrmann *et al*., 2000; Ruhí *et al*., 2009).

This study aims to: (1) characterize the sampled fishponds according to environmental variables; (2) take the inventory of aquatic macroinvertebrates assemblages in three fish ponds (pond without fish, pond stocking with fishs without artificial feed and pond stocking with fishs that receive artificial feed); (3) investigate the relationships between macroinvertebrate richness and environmental variables.

2-MATERIALS AND METHODS

2-1-Study area and sampling sites

This study was undertaken in the piscicultural farm of Blondey located in South of the Côte d'Ivoireat 25 km to Abidjan town (**Figure 1**). This farm has 27 ponds that three was used. This farm was used for Nile tilapia (*Oreochromis niloticus*) culture. All the ponds were fed by man-made lake nearby.This lake was fed inrainy season by running water from palm tree surronding the lake.

Three ponds were selected for this study:Pond without Fish (PWF); Pond Stocking With fishs without artificial Feed (PSFWF) and PondStocking with Fshs that receive artificial Feed (PSFF) in order to compare their aquatic macroinvertebratescommunity structure.

2-2-Data collection

In each pond, aquatic macroinvertebrate samplings were undertaken monthly, from november 2015 tooctober 2016 in the three selected fishponds (PWF, PSFWF and PSFF). Sampling was done usingarticial substrat (stones and branchs) in plastic baskets (20 Cm in diameter, 14 Cm of height and 0.5 Cm aperture size). In each selected fishpond, four baskets were used. Each basket was immersed at the underneath of the pond by the nylon rope. Samples were taken by collecting monthly these substrates and rinsing them through the water pond into a sieve of 1 mm aperture size. The material retained on the mesh was immediately fixed in 70% alcohol. In the laboratory, specimens were sorted and identified under a binocular magnifying glass SZ 40 to the lowest possible taxonomic level by means of the keys in Dejoux *et al*. (1981); Day *et al*. (2002 ; 2003); De Moor *etal*. (2003 a, b); Tachet *et al*. (2010); Stals & De Moor (2007). At each sampling period, before macroinvertebrate sampling, six environmental variables (transparency, temperature, pH, dissolved oxygen, oxygen redox potential and conductivity) were measured using a multiparameter digital meter. Transparency was determinate using a 20 cm diameter Secchi disk.

2-3-Data analysis

Aquatic macroinvertebrate abundance was obtained by counting all individuals per taxon and expressing the results as numbers per sample. Taxon richness was rarefied to avoid any bias related to differences in abundances between samples (Heck et al., 1975).The rarefaction was applied to the total taxonomic richness per site using the lowest abundance (13 individuals for this study) found in all sites as the target number of individuals (Oksanen et al., 2013).Shannon-Weaver diversity index (H') (Quinn & Hickey, 1990), Pielou evenness index (Pielou, 1969)(E) and frequency of occurrence (FO)were calculated. Shannon-Weaver diversity index was used to assess taxa diversity of macroinvertebrates. Evenness was used to determine aquatic macroinvertebrates distribution, regardless of species richness.Calculations were performed using the vegan package (Oksanen *et al*., 2013) for the R 3.0.2 freeware (R CoreTeam, 2013). FO is the percentage of samples in which each taxon occurred. It was calculated to classify the macroinvertebrates according to Dajoz (2000). Coefficient of similarity QS) among stations was estimated following Sorensen (1948). Sorensen index was used to assess the similarity of aquatic macroinvertebrates between different pond.

Variations in environmental variables were determined using a Kruskal–Wallis test. When the Kruskal–Wallis test was significant, a Wilcoxon test was usedfor pairwise comparison. The significance threshold was P=0.05.Before performing the comparison test, the normality of data was checked by Shapiro test.

A Canonical Correspondence Analysis (CCA) was carried out using the R package(R CoreTeam, 2013) to expresses the main relations between species and environmental variables.Taxa occurring in more than 25% of the samples, were retained. The analyses were computed with the Ade4 package (Chessel *et al*., 2004) for the R 3.0.2 freeware.These taxa were considered as principal taxa.This has been done to minimize the influence of rare taxa. Six environmental parameterswere returned for the analysis.

3. RESULTS

3-1-Environmental variables

The variations of environmental variables among the three fishponds are shown in Figure 2. The conductivity varied from 33.8 $\mu S \cdot cm^{-1}$ (PWF) to 130.2 $\mu S \cdot cm^{-1}$(PSFF). Temperature ranged between 26.2°C (PSFF) and 30.4°C (PSFF). The dissolved oxygen also, ranged between 1.6 $mg \cdot L^{-1}$(PSFF) and 11.51 $mg \cdot L^{-1}$(PWF). The pH of fishpond was values varied from 7.1 (PSFWF) to 9.04 (PSFF). The oxygen redox potential varied from 6.6 mV (PSFF) to 175.6 mV (PSFF). The transparency ranged between 9 cm (PSFF) and 24 cm (PWF).

PSFF gathered siteswith a high conductivity in comparison withthose of PWF (Wilcoxon test, M=0.0021, $P<0.05$) andPSFWF (Wilcoxon test, M= 0.0021, $P<0.05$). The highest values of dissolved oxygen were registered in PWF compared with those of PSFWF (Wilcoxon test, M= 0.0021, $P<0.05$) and PSFF (Wilcoxon test, M= 0.0021, $P<0.05$). Conversely, values for water transparency in PWFand PSFWF (Wilcoxon test, M= 0.0081, $P<0.05$) were significantly ($P<0.05$) higher than those of PSFF. There were no significant variations of temperature, pH and ORP values between fishponds (respectively Kruskal–Wallis x^2=0.52; 0.20 and 0.40, $P>0.05$).

3-2-Taxonomic richness, abundance and composition

A total of 45 taxa of aquatic macroinvertebrates belonging to 3 classes (Achetea, Gasteropoda and Insecta), 7orders (Ephemeroptera, Odonata, Heteroptera, Trichoptera, Coleoptera, Diptera and Basomatophora) and 24 families were collected in the three ponds (Table 1).The macroinvertebrate communities were dominated by insecta class (41 taxa) followed by Gasteropoda (3 taxa) and Acheta (1 taxa) (Figure 3). Inside this predominated class, the richest orderswere Odonata (12 taxa) and Diptera (9 taxa) followed by Ephemeroptera and Heteroptera (7 taxa each one), Coleoptera (4 taxa) and Trichoptera (3 taxa).The abundance of Ephemeroptera (144 - 8 specimens) and Trichoptera (421- 18 specimens) decreased respectively from ponds without fishs to ponds stocking with fishs that receive artificial feed. However, the abundance of Diptera (Chironmidae) increased (347 to 2583 specimens) in these same fish ponds (Figure 4).The pond without fishs contained the higher aquatic macroinvertebrate richness (28 taxa) whereas the lower (24 taxa) was observed in ponds stocking with fishs that receive artificial feed. The high abundance of Ephemeroptera, Trichoptera and Diptera was due to the predominance of respectively *Povilla adusta* (Polymitarcyidae), *Setodes* sp. (Leptoceridae) (Figure5) and *Nilodorum brevibucca*, *Chironomus imicola* (Chironomidae) (Figure 6) in the studied fish ponds at each sampling period. Note that *Povilla adusta and Setodes* sp.were most abundant at the ponds without fishs whereas *Nilodorum brevibucca*, *Chironomus imicola* were most abundant at the ponds stocking with fishs that receive artificial feed. The highest values of Shannon-Weaver (1, 84), evenness (0,77) and rarefied taxonomic richness (5,17) were registered in PWF and the lowest values of these parameters respectively (0,06; 0,04; 1,10) were obtained in PSFF. But, there were no significant variations of Shannon-Weaver, evenness, abundance and rarefied taxonomic richness between fishponds (Figure 7) (respectively Kruskal–Wallis x2= 0.45;0.45;0.45; 0.45 and 0.45, P>0.05).

3-3-Spatial distribution of aquatic macroinvertebrates (Frequency of occurrence (FO) and Sorensen index).

Melanoides tuberculata (Gasteropoda) and Achetawere the two commonest taxa (FO > 50%) found at all the three fishponds sampling stations. *Povilla adusta* (Ephemeroptera) and *Setodes* sp. (Trichoptera) were very frequent (FO > 50%) in PWF and PSFWF. Contrary to these taxa, *Nilodorum brevibucca* (Diptera) was mostfrequent (FO > 50%) in PSFWF and PSFF. *Bradinopyga* sp. (Odonata) was frequently (25% < FO < 50%) found at all the three fishpond selected (Table 1).

The Sorensen similarity index showed that PSFWF and PSFF were strongly similar (QS= 52.00) (Table 2). This index revealed that there was a minimum similarity between PWF and PSFWF (QS= 48.15) and PWF and PSFF (QS= 46.15) (Table 2). PWF and PSFWF shared thirteen taxa and also PSFWF and PSFF. However, twelve taxa were common between PWF and PSFF (Figure8).

The three fishponds have ten taxa (*Povilla adusta*, *Setodes* sp., *Centroptilum* sp., *Anisop* sp., *Bradinopyga* sp., *Nilodorum brevibucca*, *Chironomus imicola*, *Cryptochironomus* sp., *Melanoides tuberculata and Acheta*) in common.

3-4-Relationships between environmental variables and aquatic macroinvertebrates communities

The results of redundancy analysis revealed that the relationships between macroinvertebrate taxa andtheir habitat conditions follow mainly the first two axes (F) (Figure 4). These two axes accountedfor 76 % of the total variance. Water pH were positively correlated to axis I

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(F1). Inversely, conductivity and temperature were negatively correlated to this axe.High values of these variables were recorded at PSFF. Transparency and dissolved oxygen were negatively correlated to axis II (F2). High values of these variables were recorded at PWF. PSFF where conductivity and temperature are high werestrongly characterized by three Diptera (*Nilodorum brevibucca*, *Polypedilum deletum*, *Aedes* sp.) and one Heteroptera (*Anisops sardea*). PWF with high transparency and dissolved oxygen values were characterized by three Ephemeroptera (*Povilla adusta*, *Exeuthyplocia* sp., *Centroptilum* sp.), one Trichoptera (*Parasetodes* sp.), two Heteroptera (*Micronecta* sp, *Macrocoris flavicollis),* two Odonata *(Bradinopyga* sp, *Pseudagrion* sp.) and one Acheta. PSFWF where any environmental variables is correlated were characterized by one Ephemeroptera (*Caenomedea* sp.), one Trichoptera (*Setodes* sp), one Diptera (*Polypedilum abyssiniae)* and one Gasteropoda (*Melanoides tuberculata*).

4-DISCUSSION

The present study showed high spatial variations of environmental variablessuch as conductivity in pond stocking with fishs that receive artificial feed (PSFF). It could be related to artificial feed given to fish by human which can increase the concentration of water salts. Similar result was observed by Neumann &Dudgeon (2002) andArimoro &Ikomi (2008) in China and Nigeria.

Aquatic macroinvertebrates assemblages (45 taxa) from the three fish ponds of Blondey were characterized by the presence of Achetes, Gasteropods and Insects. The comparison of our results to those obtained by Edia (2013) and Yapo *et al*. (2015) who used respectively hand net in three tropical fish ponds of Natiokobadara, Korhogo, Northern Ivory coast andVan Veen grab in five fish ponds located in Southern Ivory coast, shows that the ecological value of ponds surveyed in this study is most important. Indeed, these authors have collected 25 and 31 taxa respectively. This difference in taxonomic richness probably reflects differences insampling methods and habitat coverage as demonstrated by Maue & Springer (2008). However, aquatic insects were dominated the macroinvertebrate fauna. This could be explained by the worldwide distribution and high tolerant of aquatic insects. This assertion was supported by Apinda-Lognouo, 2007; Florencio *et al*., 2009; Arslan *et al*., 2010; Çamur-Elipek *et al*., 2010. Odonata and Diptera were mostly the diverse groups among orders of this class with respectively 12 and 9 taxa. On the contrary, Dipterans were the most abundance quantitatively at each pond. This may be due to human influence on almost all fishponds and also to the predominance of these orders in artificial ponds in Ivory cost (Edia, 2013; Yapo et al., 2014). Moreover, the highest taxonomic richness (28 taxa) registered in the pond without fishs which could be justified by the absence of fishs as demonstrated byBamba et al., 2007;Sychra & Adámek, 2011; Edia et al., 2013.

The abundance of Ephemeroptera (144 - 8 specimens) and Trichoptera (421- 18 specimens) decreased respectively from pond without fishs to pond stocking with fishs that receive artificial feed. It was due to high water dissolved oxygen concentration in the pond without fishs. These orders are also indicators of environmental quality (Arimoro & Ikomi, 2009; Arimoro & Muller, 2009; Varandas & Cortes, 2010).

However, the highest abundance of Diptera (Chironmidae) in the pond stocking with fishs that receive artificial feed could be explained by the abundance of organic matter that mineralization could increase the production of algae in these fishponds. Leonard & Ferrington (2007) mentioned that Chironomidae are big consumers of algae. The high densities of Chironomidae at the pond stocking with fishs that receive artificial feed let us suppose that this pond is characterized by an important development of algae. According to Ouattara *et al.* (2001), stagnant waters promote algae reproduction and development so that the Chironomidae of PSFF found enough algae to fulfil their foodneed.

In this study, thepattern distribution according to environmental variables indicates that Diptera (*Nilodorum brevibucca*, *Polypedilum deletum*, *Aedes* sp.) and one Heteroptera (*Anisops sardea*) were associated to high value of conductivity and temperature.A similar result was observed by Diomandé *et al*. (2009) in Bia River (southern Côte d'Ivoire), by Yapo *et al*. (2013) in some fish farm ponds of southern Côte d'Ivoire and by Ogbeibu (2001) who observed a significant positive correlation between density and water temperature intemporary pond in Okomu Forest Reserve. Ephemeroptera (*Povilla adusta*, *Exeuthyplocia* sp., *Centroptilum* sp.), one Trichoptera (*Parasetodes* sp.) were associated to high value of Transparency and dissolved oxygen. This could be related to good water quality as demonstrated by Yapo *et al*. (2017) in five fish farms (Layo, Banco, Azaguié, Anyama I and Anyama II) in southern Côte d'Ivoire.

CONCLUSION

This study allowed us to identify 45 taxa of aquatic macroinvertebrates in an artificial non-stocked pond.The settlement was dominated by Odonata and Diptera. The maximum richness was observed in PWF where transparency and dissolved oxygen arehigh. This study revealed that water quality of the PWF is good as supported by the values of biological indices and by presence of orders Ephemeroptera and Trichoptera.

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Yapo M. L., Edia O. E., Sylla S., Atse B. C. &Kouassi P., 2017. 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*, 13: 45-61.

E 1 : PWF

E 4 : PSFWF

E 24 : PSFF

Figure 1: Location of the study area

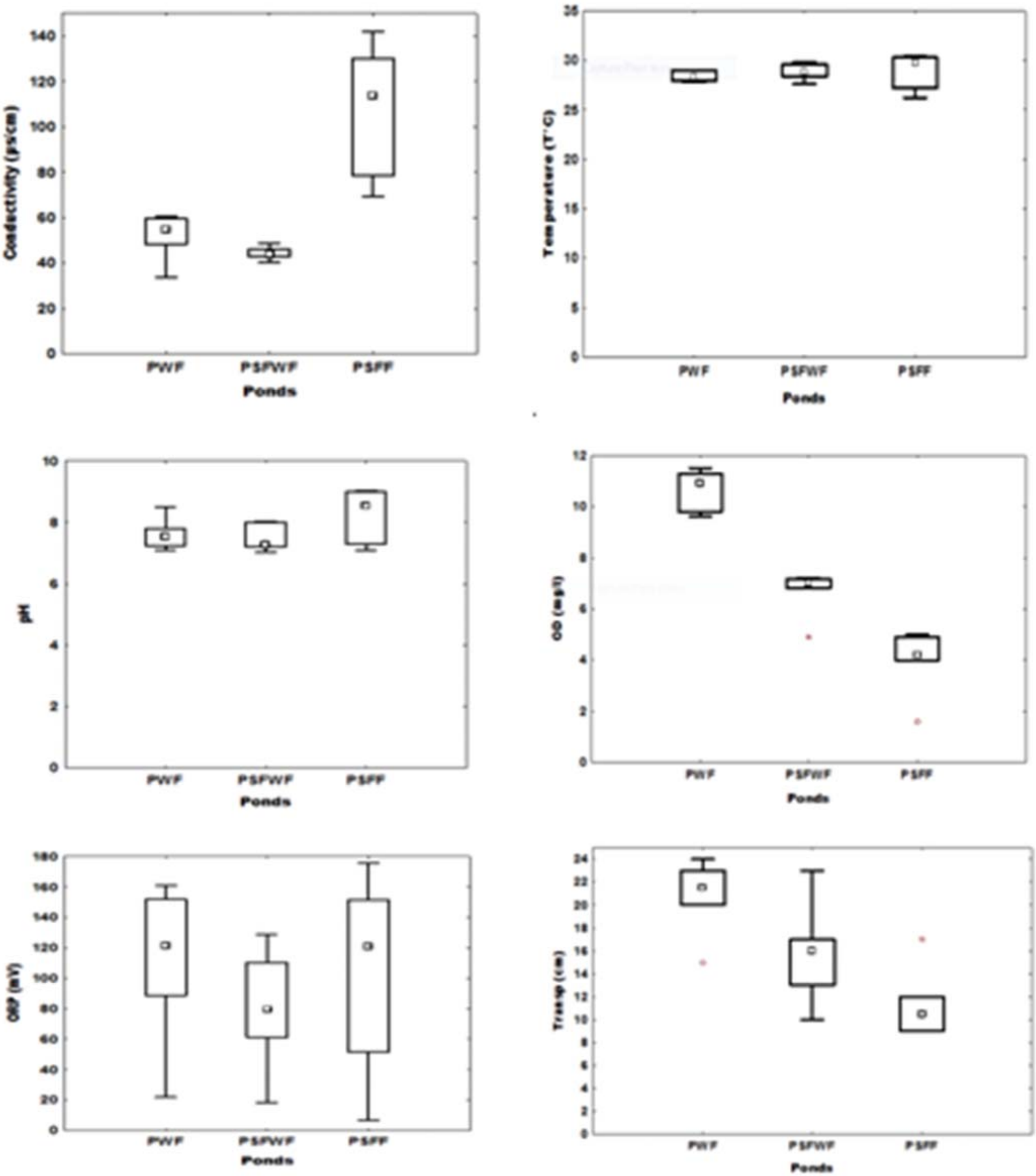

figure 2 : Box-plots showing differences in environmental variables between three fish ponds (PWF ; PSFWF ; PSFF). Different letters on box-plots denote significant

differences between them (P<0.05; Mann-Whitney test). (PWF= Pond Without Fishs ; PSFWF= Pond Stocking With fish without artificial Feed ; PSFF= pond stocking with fishs that receive artificial feed).

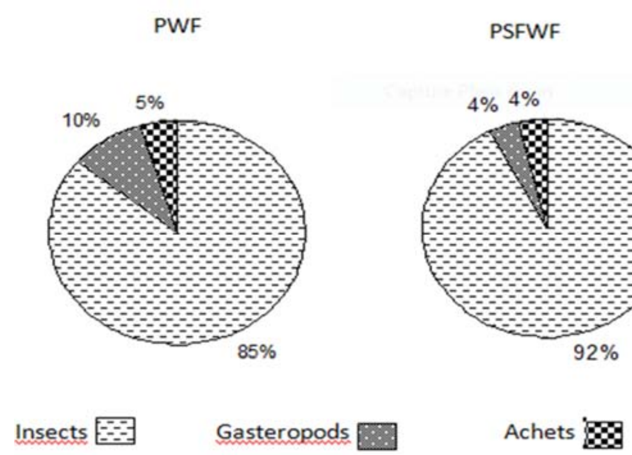

Figure 3: Repartition of macroinvertebrates class on the three fish ponds (PWF= Pond without Fish ; PSWF= Pond Stocking with fish without artificial Feed ; PSFF= pond stocking with fishs that receive artificial feed.

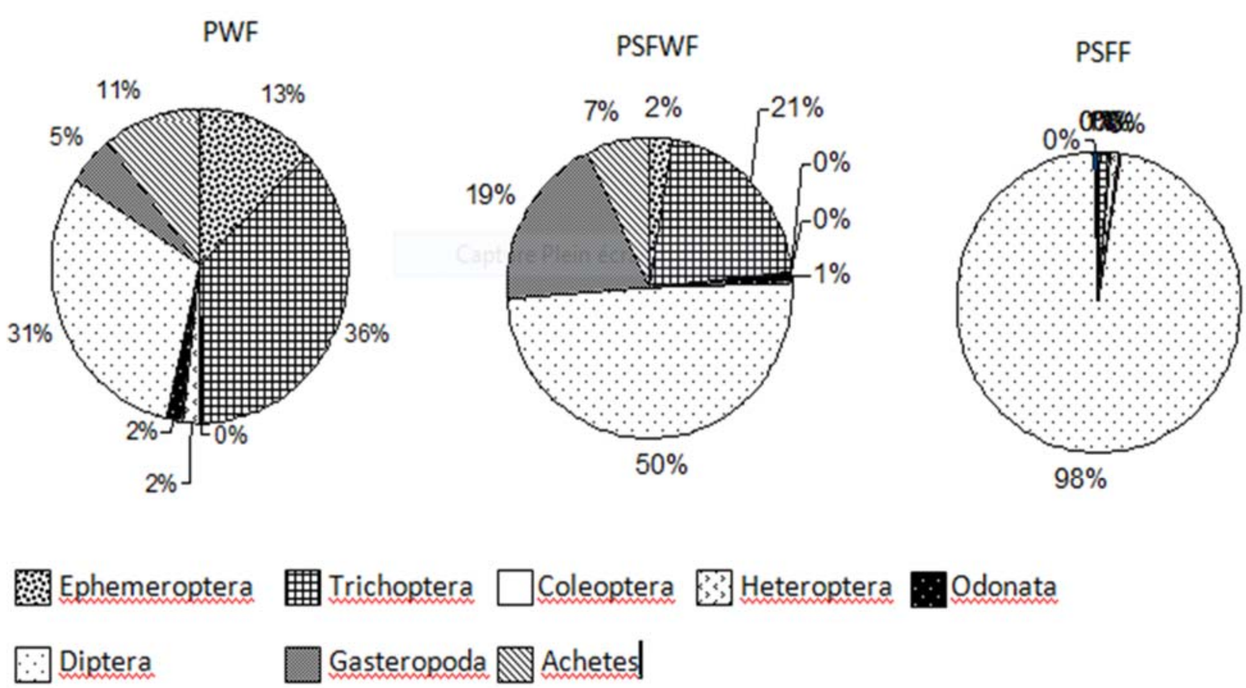

Figure 4: Taxonomic composition of the three fish ponds (PWF= Pond without Fish ; PSWF= Pond Stocking with fish without artificial Feed ; PSFF= pond stocking with fishs that receive artificial feed.

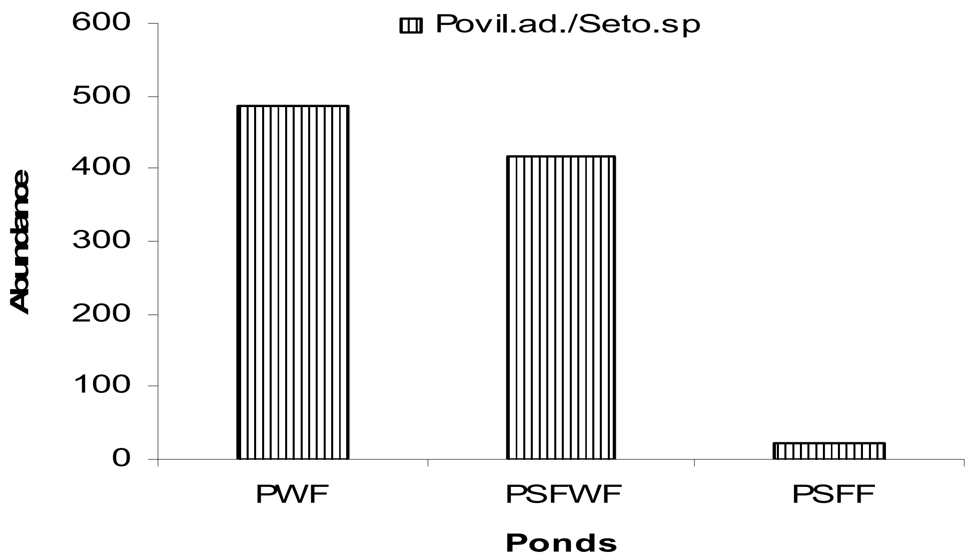

Figure 5: Abundance of *Povilla adusta* and *Setodes* sp. (Polymitarcidae and Leptoceridae) in three different fish ponds.

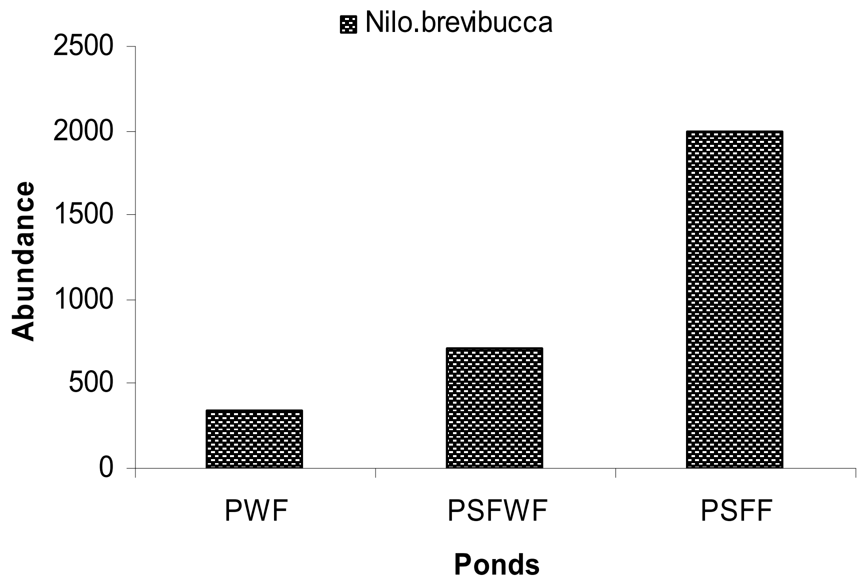

Figure 6: Abundance of *Nilodorum brevibucca* (Chironomidae) in three different fish ponds

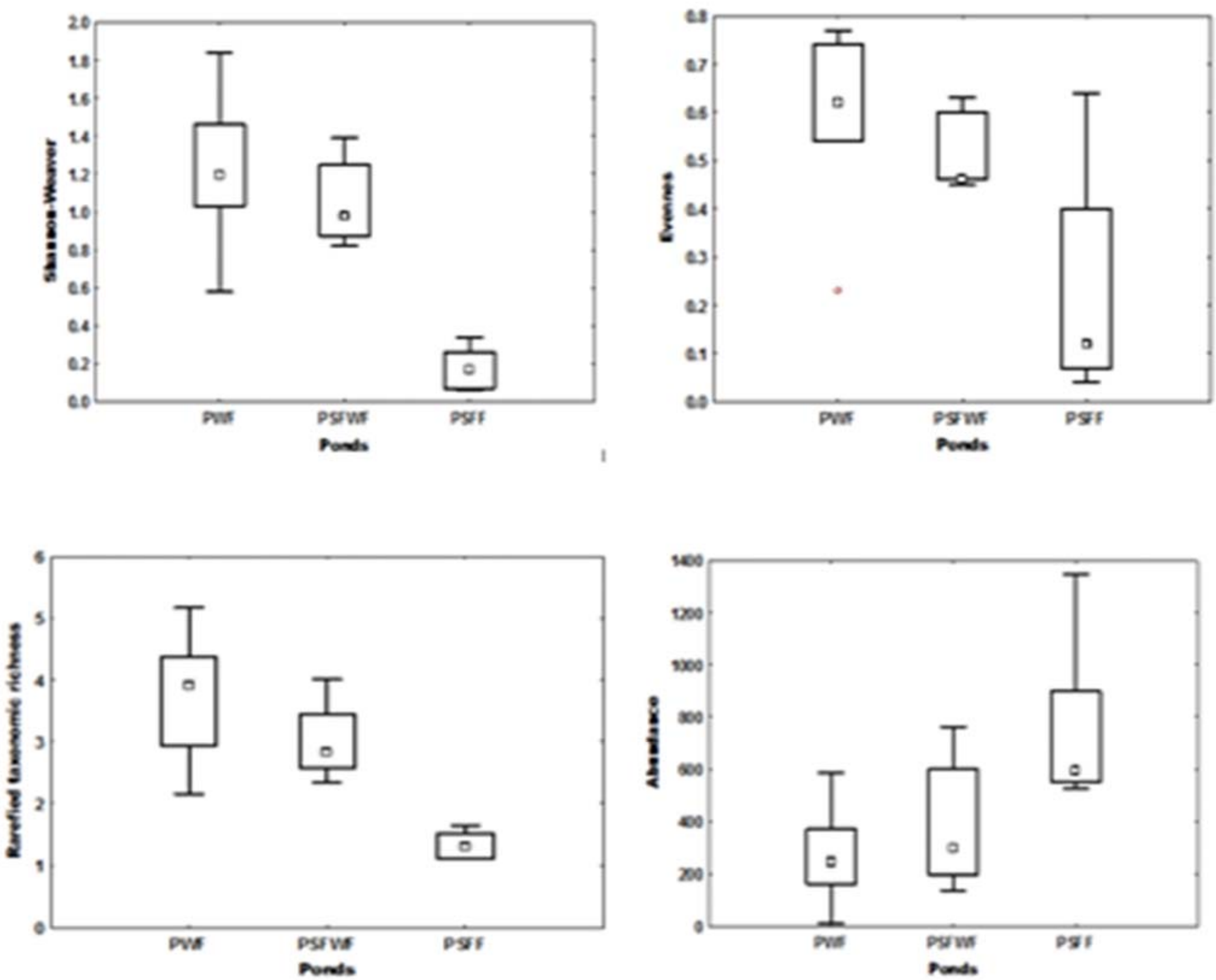

Figure 7: Box-plots showing variations in biotic parameters between three fish ponds (PWF ; PSFWF ; PSFF). No significant variations between clusters (Kruskal–Wallis test, x2= 0.45, P>0.05) (PWF= Pond Without Fishs ; PSFWF= Pond Stocking With fish without artificial Feed ; PSFF= pond stocking with fishs that receive artificial feed).

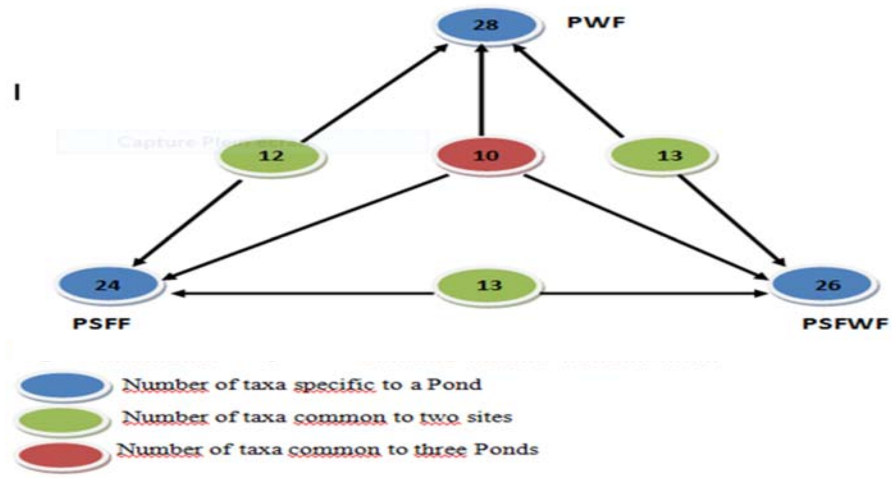

Figure 8 : Taxonomic composition similarity between different Ponds.

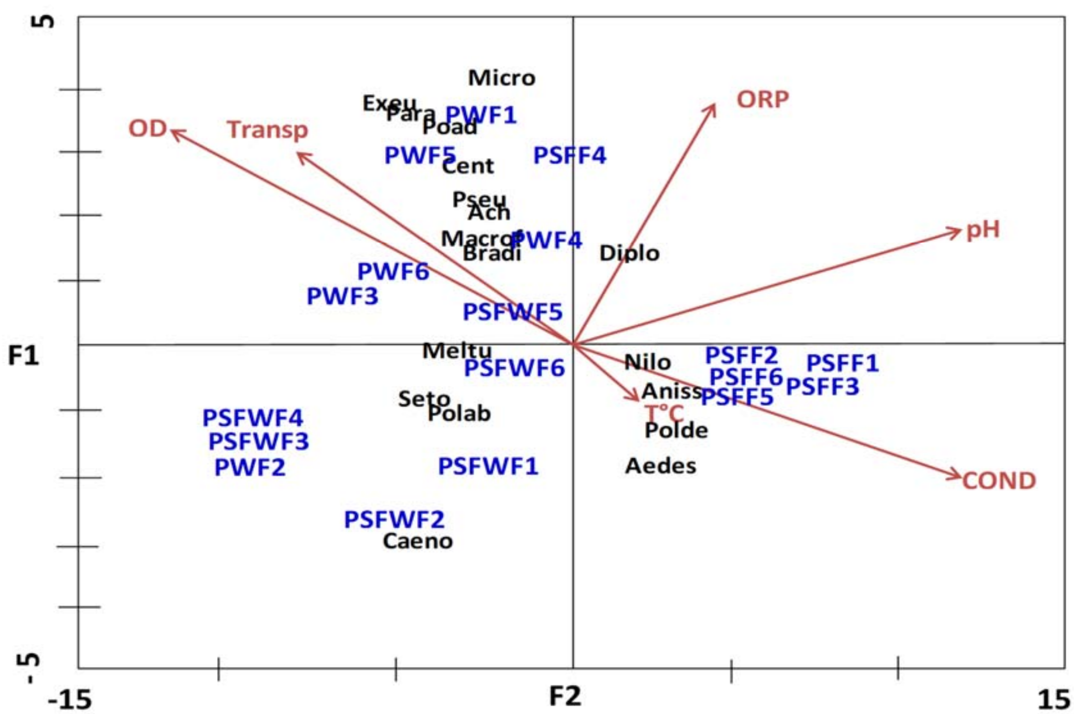

Figure 9. Canonical correspondence analysis carried out with selected environmental Variables and with the dominant macroinvertebrate taxa. Taxa codes

Ach : Acheta ; **Aedes** : *Aedes* sp. ; **Aniss**: *Anisops sardea*; **Bradi** : *Bradinopyga* sp. ; **Caeno** :*Caenomedea* sp. ; **Cent** : *Centroptilum* sp. ; **Diplo** : *Diplonychus* sp. ; **Exeu** : *Exeuthyplocia* sp. ; **Macrof** : *Macrocoris flavicollis* ; **Meltu** : *Melanoides tuberculata* ; **Micro** :

Micronecta sp. ; **Nilo** : *Nilodorum brevibucca*. ; **Para :** *Parasetodes* sp. ; **Poad :** *Povilla adusta* **;** **Polab** : *Polypedilum abyssiniae* ; **Polde :** *Polypedilum deletum* ; **Pseu** : *Pseudagrion* sp. ; **Seto :***Setodes* sp.**.**

Table 1. List of the aquatic macroinvertebrates taxa found in the three fish ponds of Blondey. ***Very frequent (FO > 50%), **frequent (25% ≤ FO ≥ 50%), *rare occurrence (FO < 25%).

				Fish ponds		
Class	**Order**	**Family**	**Taxon**	**PWF**	**PSFWF**	**PSFF**
Insecta	Ephemeroptera	Polymitarcyidae	*Povilla adusta*	***	***	*
			Exeuthyplocia sp.	**		
			Povilla sp.	*	*	
		Leptophlebiidae	*Adenophlebiodes* sp.		*	
		Caenidae	*Caenomedea* sp.	**		
			Caenodes sp.	*		
		Baetidae	*Centroptilum* sp.	***	**	*
	Trichoptera	Leptoceridae	*Setodes* sp.	***	***	*
			Parasetodes sp.		*	
		Ecnomidae	*Ecnomus* sp.		*	
	Coleoptera	Hydrophilidae	*Amphiops* sp.		*	
			Enochrus sp.			*
		Dytiscidae	*Bidessus* sp.	*		
			Hydaticus sp.			*
		Hydraenidae				*
		Elmidae				*
	Heteroptera	Corixidae	*Corixini* sp.	*		
			Micronecta sp.	**		
		Belostomidae	*Diplonychus* sp.	**		**
			Macrocoris flavicollis	**	*	
		Notonectidae	*Anisop sardea*			**
				*		
			Anisop sp.	*	*	*
		Naucoridae	*Naucoris* sp.	*		
	Odonata	Libellulidae	*Macrodiplax cora*	*		
			Bradinopyga sp.	**	**	**
			Zygonyx torrida		*	
			Zyxomma petiolatum		*	
			Trithemis verneri		*	*

			Trithemis dorsalis	*		
			Parazyxoma flavicans		*	*
			Tramea transmarina	*		
		Coenagriidae	*Ceriagrion* sp.	*		
			Pseudagrion sp.	**	*	
		Gomphidae	*Ictinogomphus* sp.		*	*
			Paragomphus sp.	**		**

Table 1 (Extented).

Class	Order	Family	Taxon	Fish ponds PWF	PSFWF	PSFF
	Diptera	Chironomidae	*Nilodorum brevibucca.*	*	***	***
			Cryptochironomus sp.	*	*	*
			Polypedilum deletum			**
			Stictochironomus sp.		*	*
			Chironomus imicola	*	*	**
			Polypedilum abyssiniae		***	
		Orthocladiinae	*Cricotopus* sp.		*	
		Culicidae	*Aedes* sp.			**
		Tanypodinae	*Ablabesmyia pictipes*	*		
Gasteropoda	Basomatophora	Thiaridae	*Melanoides tuberculata*	***	***	**
		Pomatiopsidae	*Tomichia* sp.		*	
		Planorbidae	*Biomphalaria pffeiferi*			**
Acheta				***	***	**
3	**7**	**24**	**45**	**28**	**26**	**24**

Table 2. Sorensen similarity index of aquatic macroinvertebrate's communities recorded in the different Ponds

Ponds	**PWF**	**PSFWF**	**PSFF**
PWF		48.15	46.15
PSFWF	48.15		**52**
PSFF	46.15	**52**	