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

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Abstract

The present study was aimed to assess the effect of fish feeding on the diversity and structure of aquatic macroinvertebrates in fishponds of Blondéy in Southern Côte d'Ivoire. It was conducted in three fish ponds: a Pond without Fish (PWF), a Pond Stocking with Fish without artificial Feed (PSFWF) and a Pond Stocking with Fishes that receive artificial Feed (PSFF). In each pond, aquatic macroinvertebrates samplings were undertaken monthly with artificial substrate from November 2015 to October 2016. A total of 45 taxa belonging to three classes, seven orders and 24 families were collected. Taxa richness is higher in PWF and PSFF and lower in PSFWF. The abundance of Ephemeroptera and Trichoptera decreased respectively from PWF (144 and 421) to PSFF (8 and 18). However, the abundance of Diptera (Chironmidae) was increased (347 to 2583 specimens) in these same fishponds.

Keywords: Aquatic macroinvertebrates, fishponds, effect, feeding, diversity and structure, Côte d'Ivoire

1. Introduction

Fishpond ecosystems have recently been recognized as important habitats for the maintenance of biodiversity particularly for macro fauna biodiversity^[1, 2]. Aquatic macro invertebrates are generally used in bioassessment programs for determining the ecological quality of fishpond^[3, 4, 5]. The identification of species and their distribution patterns provide more information for monitoring and conserving these ecosystems. Moreover aquatic macroinvertebrates play an important role in aquatic ecosystems functioning^[6]. At the larval stage, they constituted the principal nutritive fauna of fish or many predatory organisms and also ensured the nutrients energy flux in aquatic ecosystems^[7, 8].

In Côte d'Ivoire, several studies have been conducted on the distribution, taxonomic abundance and systematic of macroinvertebrates in the running waters^[9, 4, 10, 11, 12]. However, without studies of^[4, 13, 14, 15, 16, 17, 5] 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 role in the conservation of aquatic biodiversity^[18, 15]. Nowadays, aquatic macroinvertebrates are little know concerning ecological functioning of those ecosystems^[19, 20].

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 fish without artificial feed and pond stocking with fish 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 Blondéy located in South of the Côte d'Ivoire at 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 in rainy season by running water from palm tree surrounding the lake.

Three ponds were selected for this study: Pond without Fish (PWF); Pond Stocking with fishes without artificial Feed (PSFWF) and Pond Stocking with Fshs that receive

artificial Feed (PSFF) in order to compare their aquatic macroinvertebrates community structure.

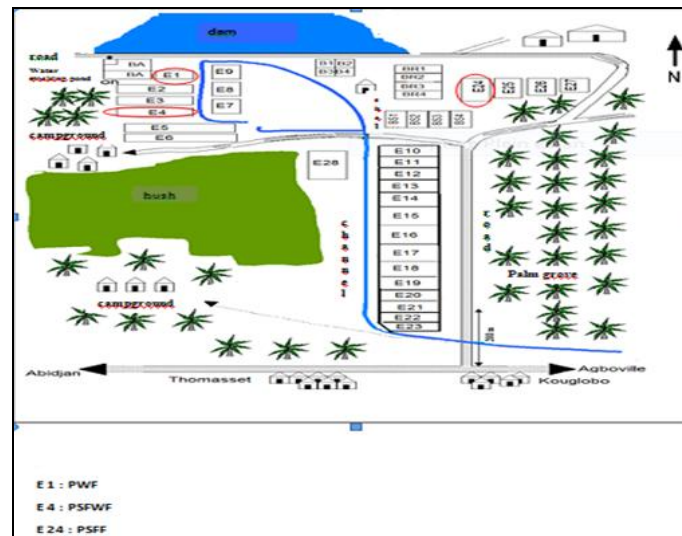


Fig 1: Location of the study area

2.2. Data collection

In each pond, aquatic macroinvertebrate samplings were undertaken monthly, from November 2015 to October 2016 in the three selected fishponds (PWF, PSFWF and PSFF). Sampling was done using artificial substrat (stones and branches) 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 [21, 22, 23, 24, 25, 7, 26]. 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 determined 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 [27]. 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 [28]. Shannon-Weaver diversity index (H') [29], Pielou evenness index [30] (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 [28] for the R 3.0.2 freeware [31]. FO is the percentage of samples in which each taxon occurred. It was calculated to classify the macroinvertebrates according to [32]. Coefficient of similarity (QS) among stations was estimated following [33]. Sorensen

index was used to assess the similarity of aquatic macroinvertebrates between different ponds.

Variations in environmental variables were determined using a Kruskal–Wallis test. When the Kruskal–Wallis test was significant, a Wilcoxon test was used for 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 [31] to express 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 [34] 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 parameters were returned for the analysis.

3. Results

3.1. Environmental variables

The variations of environmental variables among the three fishponds are shown in Fig. 2. The conductivity varied from $33.8 \mu\text{S}\cdot\text{cm}^{-1}$ (PWF) to $130.2 \mu\text{S}\cdot\text{cm}^{-1}$ (PSFF). Temperature ranged between 26.2°C (PSFF) and 30.4°C (PSFF). The dissolved oxygen also, ranged between $1.6 \text{ mg}\cdot\text{L}^{-1}$ (PSFF) and $11.51 \text{ mg}\cdot\text{L}^{-1}$ (PWF). The pH values of fishpond was 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 sites with a high conductivity in comparison with those of PWF (Wilcoxon test, $M=0.0021$, $P<0.05$) and PSFWF (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 PWF and 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 $\chi^2=0.52$; 0.20 and 0.40, $P>0.05$).

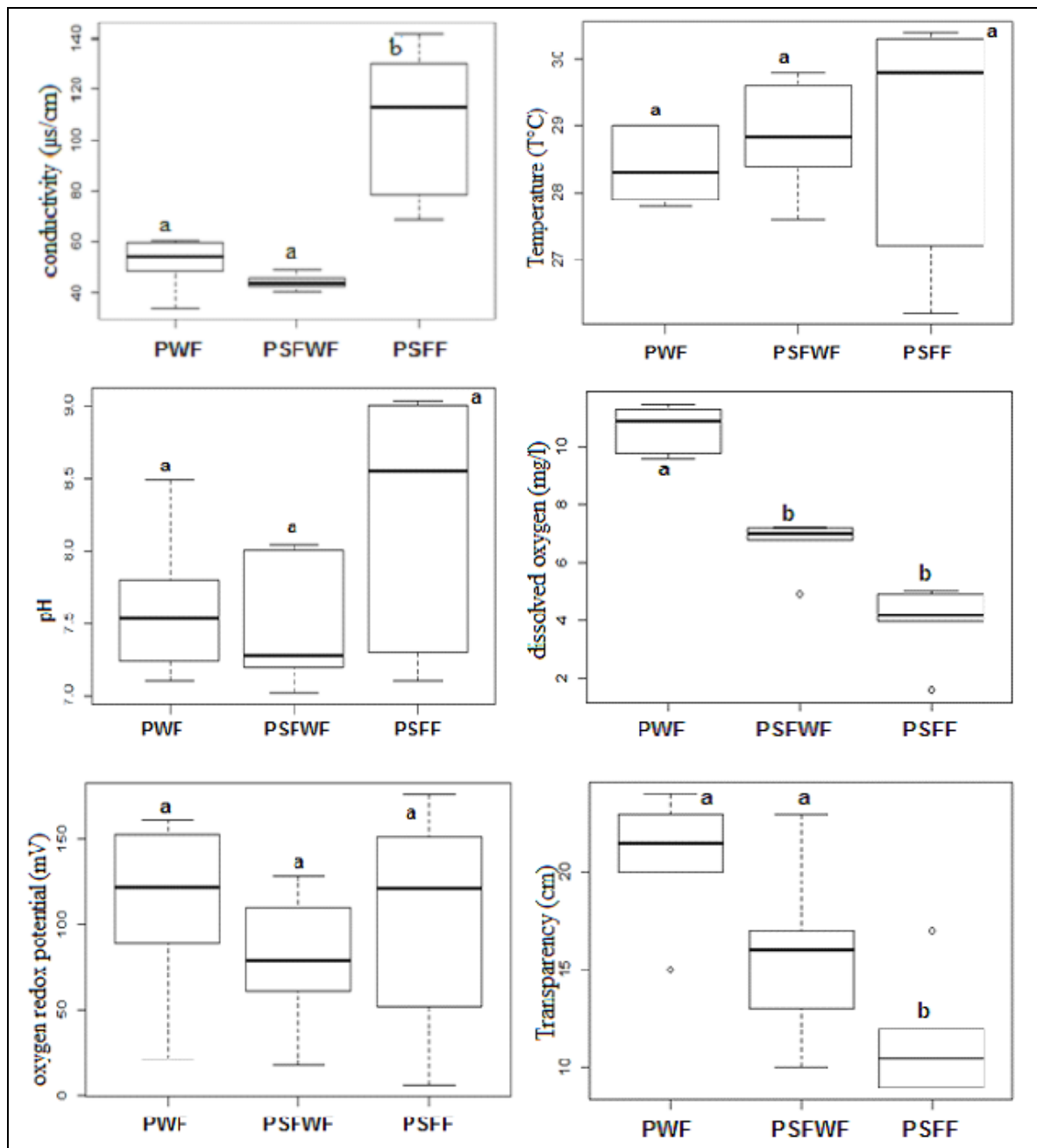


Fig 2: Box-plots showing differences in environmental variables between three fish ponds (PWF; PSFWF ; PSFF). Different letters on box-plots denote significant differences between them ($P < 0.05$; Mann-Whitney test). (PWF= Pond Without Fishes ; PSFWF= Pond Stocking With fish without artificial Feed ; PSFF= pond stocking with Fishes that receive artificial Feed).

3.2. Taxonomic richness, abundance and composition

A total of 45 taxa of aquatic macroinvertebrates belonging to 3 classes (Achetea, Gasteropoda and Insecta), 7 orders (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) (Fig. 3). Inside this predominated class, the richest orders were 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 fish to ponds stocking with fish that receive artificial feed. However, the abundance of Diptera (Chironomidae) increased (347 to 2583 specimens) in these same fish ponds (Fig. 4). The pond without fish contained the higher aquatic macroinvertebrate richness (28 taxa) whereas the lower (24

taxa) was observed in ponds stocking with fish 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) (Fig. 5) and *Nilodorum brevivucca*, *Chironomus imicola* (Chironomidae) (Fig. 6) in the studied fish ponds at each sampling period. Note that *Povilla adusta* and *Setodes* sp. were most abundant at the ponds without fish whereas *Nilodorum brevivucca*, *Chironomus imicola* were most abundant at the ponds stocking with fish 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 (Fig. 7) (respectively Kruskal-Wallis $\chi^2 = 0.45; 0.45; 0.45; 0.45$ and $0.45, P > 0.05$).

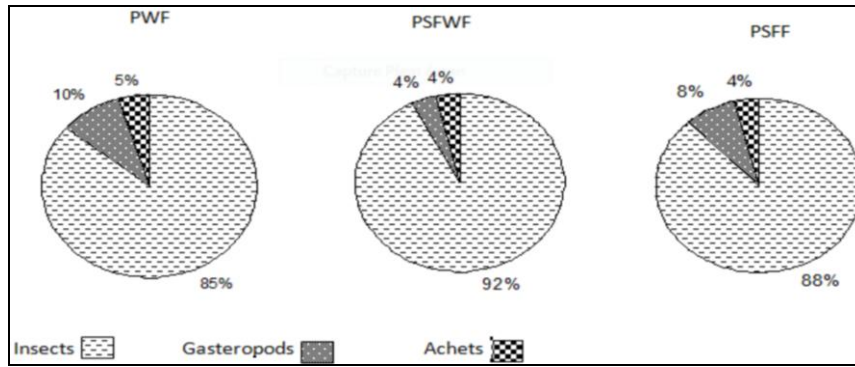


Fig 3: Repartition of macroinvertebrates class on the three fish ponds (PWF= Pond without Fish; PSFWF= Pond Stocking with fish without artificial Feed ; PSFF= pond stocking with fishes that receive artificial feed).

Table 1: List of the aquatic macroinvertebrates taxa found in the three fish ponds of Blondéy.

Class	Order	Family	Taxon	Fish ponds			
				PWF	PSFWF	PSFF	
Insecta	Ephemeroptera	Polymitarcyidae	<i>Povilla adusta</i>	***	***	*	
			<i>Exeuthyplocia</i> sp.	**			
			<i>Povilla</i> sp.	*	*		
		Leptophlebiidae	<i>Adenophlebiodes</i> sp.		*		
			Caenidae	<i>Caenomedea</i> sp.	**		
				<i>Caenodes</i> sp.	*		
		Baetidae	<i>Centroptilum</i> sp.	***	**	*	
		Trichoptera	Leptoceridae	<i>Setodes</i> sp.	***	***	*
				<i>Parasetodes</i> sp.		*	
	Ecnomidae		<i>Ecnomus</i> sp.		*		
	Coleoptera	Hydrophilidae	<i>Amphiops</i> sp.		*		
			<i>Enochrus</i> sp.			*	
		Dytiscidae	<i>Bidessus</i> sp.	*			
			<i>Hydaticus</i> sp.			*	
		Hydraenidae			*		
		Elmidae			*		
	Heteroptera	Corixidae	<i>Corixini</i> sp.	*			
			<i>Micronecta</i> sp.	**			
		Belostomidae	<i>Diplonychus</i> sp.	**		**	
			<i>Macrocoris flavicollis</i>	**	*		
		Notonectidae	<i>Anisop sardea</i>	*		**	
			<i>Anisop</i> sp.	*	*	*	
	Naucoridae	<i>Naucoris</i> sp.	*				
	Odonata	Libellulidae	<i>Macrodiplax cora</i>	*			
			<i>Bradinygya</i> sp.	**	**	**	
			<i>Zygonyx torrida</i>		*		
			<i>Zyxomma petiolatum</i>		*		
			<i>Trithemis vernerii</i>		*	*	
			<i>Trithemis dorsalis</i>	*			
			<i>Parazyxoma flavicans</i>		*	*	
			<i>Tramea transmarina</i>	*			
			Coenagriidae	<i>Ceriagrion</i> sp.	*		
				<i>Pseudagrion</i> sp.	**	*	
Gomphidae	<i>Ictinogomphus</i> sp.		*	*			
	<i>Paragomphus</i> sp.	**		**			
Diptera	Chironomidae	<i>Nilodorum brevivucca</i> .	*	***	***		
		<i>Cryptochironomus</i> sp.	*	*	*		
		<i>Polypedilum deletum</i>			**		
		<i>Stictochironomus</i> sp.		*	*		
		<i>Chironomus imicola</i>	*	*	**		
		<i>Polypedilum abyssiniae</i>		***			
	Orthoclaadiinae	<i>Cricotopus</i> sp.		*			
	Culicidae	<i>Aedes</i> sp.			**		
	Tanypodinae	<i>Ablabesmyia pictipes</i>	*				
Gasteropoda	Basomatophora	Thiaridae	<i>Melanoides tuberculata</i>	***	***	**	
		Pomatiopsidae	<i>Tomichia</i> sp.		*		
		Planorbidae	<i>Biomphalaria pfeiferi</i>			**	
Acheta			***	***	**		
3	7	24	45	28	26	24	

***Very frequent (FO > 50%), **frequent (25% ≤ FO ≤ 50%), *rare occurrence (FO < 25%).

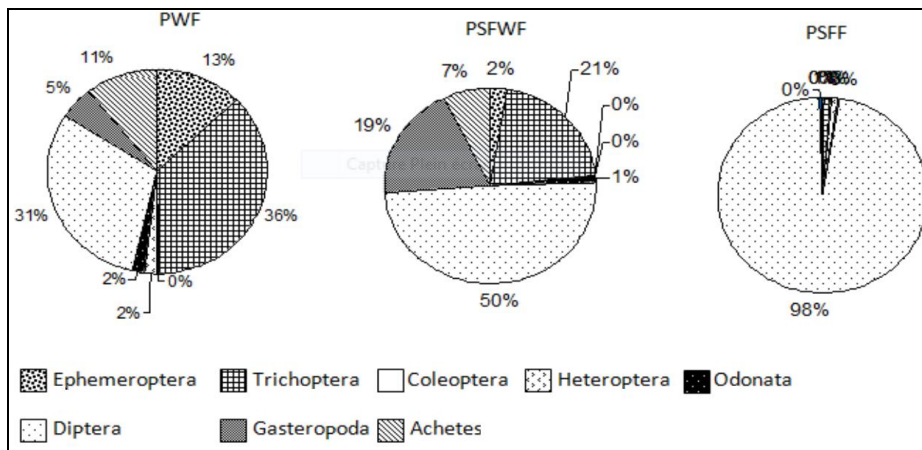


Fig. 4: Taxonomic composition of the three fish ponds (PWF= Pond without Fish ; PSFW= Pond Stocking with fish without artificial Feed ; PSFF= pond stocking with fishes that receive artificial feed).

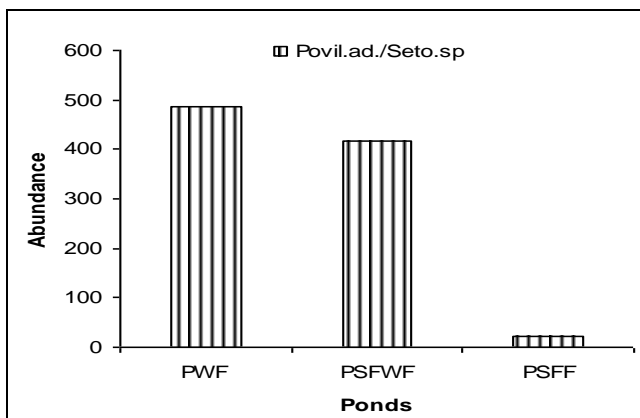


Fig 5: Abundance of *Povilla adusta* and *Setodes* sp. (Polymitarcidae and Leptoceridae) in three different fish ponds.

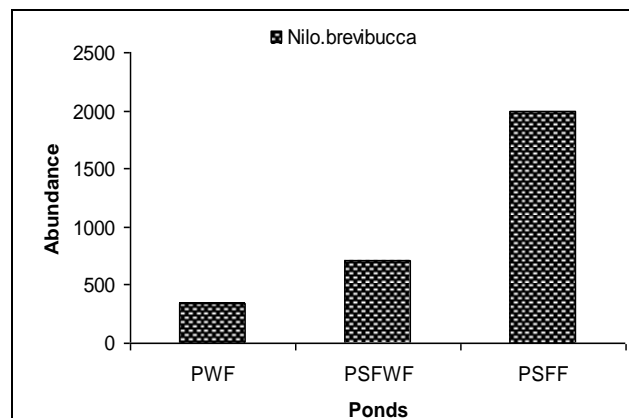


Fig 6: Abundance of *Nilodorum brevibuca* (Chironomidae) in three different fish ponds.

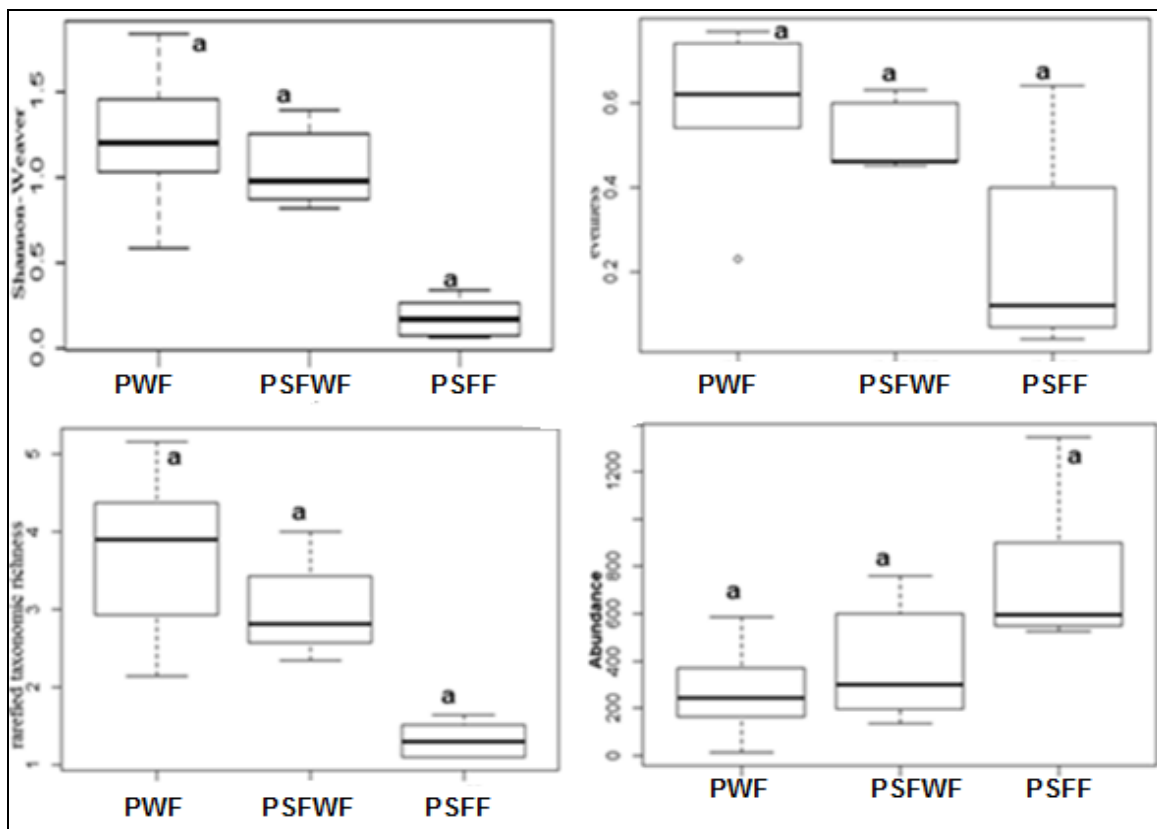


Fig 7: Box-plots showing variations in biotic parameters between three fish ponds (PWF; PSFW; PSFF). No significant variations between clusters (Kruskal–Wallis test, $\chi^2=0.45$, $P>0.05$) (PWF= Pond without Fishes; PSFW= Pond Stocking With fish without artificial Feed ; PSFF= pond stocking with fishes that receive artificial feed).

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 brevibuca* (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 brevibuca*, *Chironomus imicola*, *Cryptochironomus* sp., *Melanoides tuberculata* and *Acheta*) in common.

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	

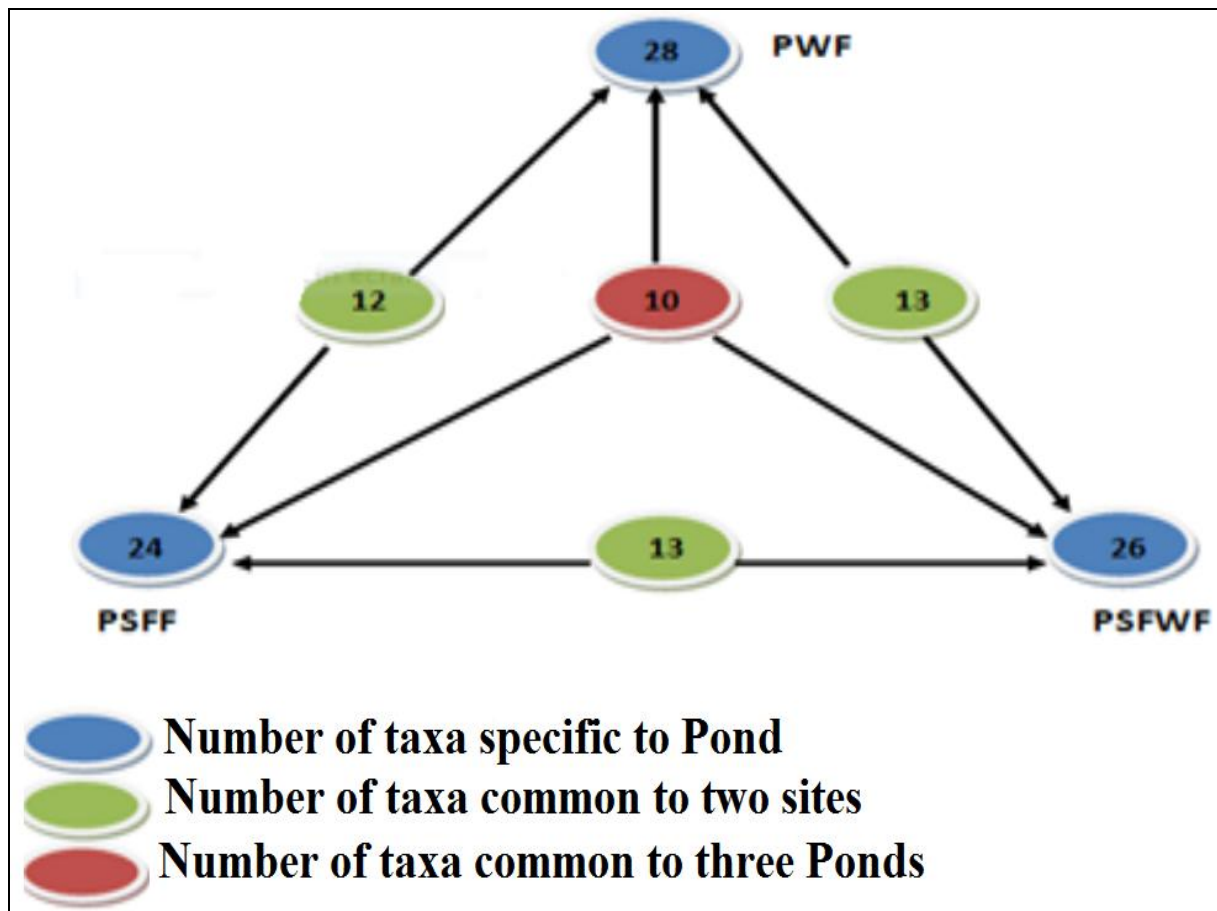


Fig 8: Taxonomic composition similarity between different Ponds.

3.4. Relationships between environmental variables and aquatic macroinvertebrates communities

The results of redundancy analysis revealed that the relationships between macroinvertebrate taxa and their habitat conditions follow mainly the first two axes (F) (Fig. 9). These two axes accounted for 76 % of the total variance. Water pH were positively correlated to axis I (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 were strongly characterized by three Diptera (*Nilodorum*

brevibuca, *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*).

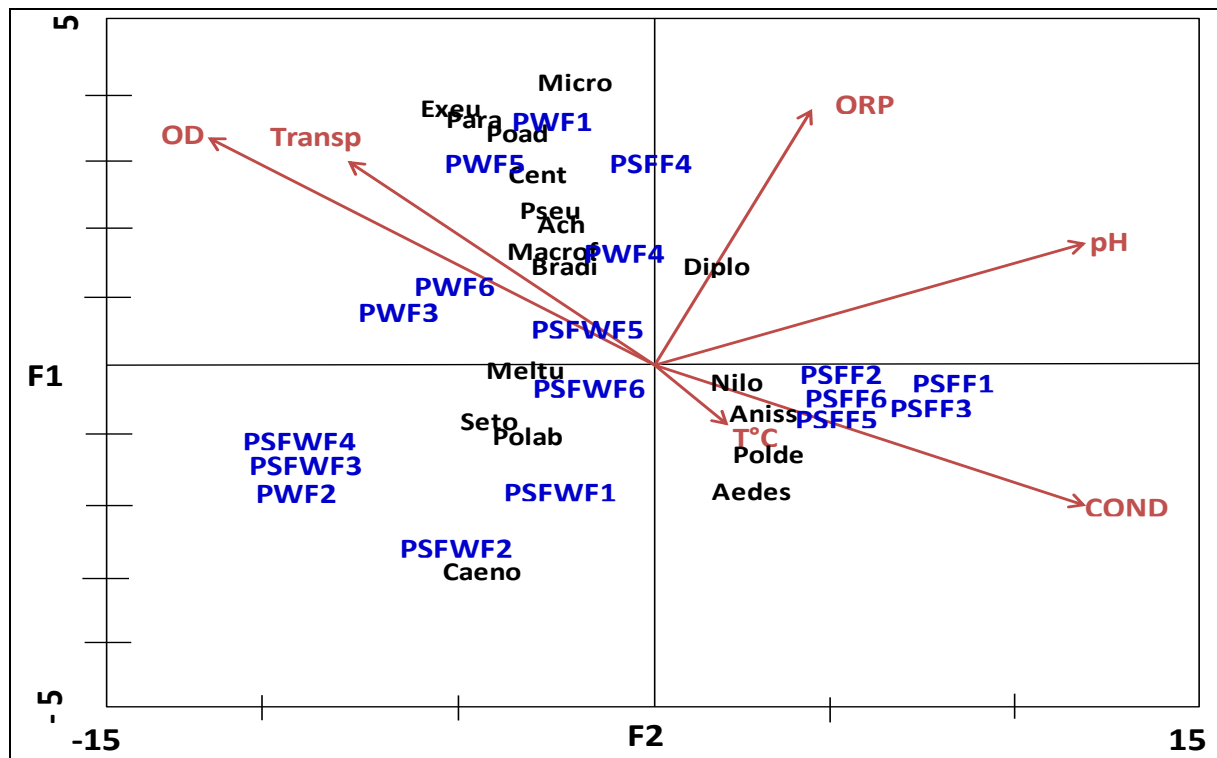


Fig 9: Canonical correspondence analysis carried out with selected environmental Variables and with the dominant macroinvertebrate taxa. Taxa codes

Ach : Acheta ; Aedes : *Aedes* sp. ; Aniss: *Anisops sardea*; Bradi : *Bradinopyga* sp. ; Caeno : *Caenomedea* sp. ; Cent : *Centropilum* 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.

4. Discussion

The present study showed high spatial variations of environmental variables such as conductivity in pond stocking with fishes 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 [35] and [36] in China and Nigeria.

Aquatic macroinvertebrates assemblages (45 taxa) from the three fish ponds of Blondéy were characterized by the presence of Achetes, Gasteropods and Insects. The comparison of our results to those obtained by [4] and [17] who used respectively hand net in three tropical fish ponds of Natiokobadara, Korhogo, Northern Ivory coast and Van 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 in sampling methods and habitat coverage as demonstrated by [37]. However, aquatic insects were dominated the macroinvertebrate fauna. This could be explained by the worldwide distribution and high tolerance of aquatic insects. This assertion was supported by [2, 38, 39, 40]. 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 abundant 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 coast [4, 16]. Moreover, the highest

taxonomic richness (28 taxa) registered in the pond without fishes which could be justified by the absence of fishes as demonstrated by [41, 42, 4].

The abundance of Ephemeroptera (144 - 8 specimens) and Trichoptera (421- 18 specimens) decreased respectively from pond without fishes to pond stocking with fishes that receive artificial feed. It was due to high water dissolved oxygen concentration in the pond without fishes. These orders are also indicators of environmental quality [43, 44, 45].

However, the highest abundance of Diptera (Chironomidae) in the pond stocking with fishes that receive artificial feed could be explained by the abundance of organic matter that mineralization could increase the production of algae in these fishponds. [46] mentioned that Chironomidae are big consumers of algae. The high densities of Chironomidae at the pond stocking with fishes that receive artificial feed let us suppose that this pond is characterized by an important development of algae. According to [46], stagnant waters promote algae reproduction and development so that the Chironomidae of PSFF found enough algae to fulfil their food need.

In this study, the pattern 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 [48] in Agnèby River (southern Côte d'Ivoire), by [15] in some fish farm ponds of southern Côte d'Ivoire and by [49] who observed a significant positive correlation between density and water temperature in temporary pond in Okomu Forest Reserve. Ephemeroptera (*Povilla adusta*, *Exeuthyplocia* sp., *Centropilum* 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 [5] in five fish farms (Layo, Banco, Azaguié, Anyama I and Anyama II) in southern Côte d'Ivoire.

5. Conclusion

This study identifies 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 are high. 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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