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Fishpond colonization by aquatic macroinvertebrates: case of Blondey (Côte d'Ivoire; West Africa)

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Abstract
The diversity of aquatic macroinvertebrates and their colonization were studied in a fishpond of blondey at two growth stages of fish breeding, juvenil stage and adult stage. Samples were taken monthly with artificial substrates during three months for juvenil stage and six months for adult stage. A total of 32 taxa were recorded. Insecta was the most dominant class on both juvenil stage and adult stage in number of taxa and abundance, followed by Gasteropoda and Acheta. The taxa composition and the diversity of aquatic macroinvertebrates were progressively increased in juvenil stage. Conversely these two parameters observed a heterogeneous dynamic in adult stage. According to the functional feeding groups, the pioneer colonists were mainly Omnivores (e.g. *Setodes* sp.) during the juvenil stage. This group was followed by the Grazers and Predators at the same period. And then, during the adult stage, Detritivores (e.g. Chironomids) appeared and dominated the aquatic invertebrates always with the presence of Grazers and Predators while the Omnivores decreased and disappeared at the end of this stage. This way, the Omnivores are the principal colonists of fishpond during juvenil stage and then the Detritivores appear and dominate the macroinvertebrate's functional feeding groups while the adult stage.

Keywords: fishpond, macroinvertebrates, succession, diversity

1. Introduction

Aquatic macroinvertebrates play an important role in aquatic ecosystem functioning **(**Dunbar *et al.*, 2010) [2]. At the larval stage, they constituted the principal nutritive fauna of fish or many predatory organisms (Broyer & Curtet, 2010; Tach *et al*., 2010) [3, 30]. So these invertebrates could contribute to reduce production costs of fish breeding. Aquatic macroinvertebrates are also generally used in bioassessment programs for determining the ecological quality of fishpond (Moretti & Callisto, 2005; Edia, 2013; Yapo *et al*., 2017) [16, 13, 36]. The identification of species and their distribution patterns provide more information for monitoring and conserving these ecosystems. Fishpond ecosystems have recently been recognized as important habitats for the maintenance of biodiversity (Oertli *et al*., 2005) [21] particularly for macrofauna biodiversity (Apinda-Lognouo, 2007) [1].

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) [15, 13, 17, 4, 11, 19]. However, only Edia (2013) [13] and Yapo *et al*. (2007; 2012; 2013; 2014; 2015; 2017) [31-36] are focussed on diversity and systematic of aquatic insects of fishpond. Moreover, concerning recolonization of those man made habitats by aquatic macroinvertebrates in this country, there are no studies on this topic. Now the colonization rate can be considered as indicators of local factors, mainly the physicochemical parameters of water, fish stock composition, the type of fishpond, water level fluctuation, intensifying interventions and food conditions of biotope. The aims of this study, are to (i) characterize the sampling sites according to the environmental variables, (ii) describe aquatic macroinvertebrates succession in a fishpond of Blondey following water filling and (iii) investigate the relationships between aquatic macroinvertebrates feeding groups distribution and the environmental variables of the fishpond.

2. Material and Methods

2.1 Study area and sampling sites

This study was undertaken in the piscicultural farm of Blondey located in South Côte d'Ivoire at 25 km to Abidjan (Economic capital). This farm has 27 ponds that one (E28) was used (Figure 1). This farm 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 come from palm plantation surronding the lake.

The pond selected for this study was without Fish (PWF). It was drained during September 2016 corresponding to the dry season. The width, the length, the area and the depth of the pond were respectively 18 m, 25 m, 450 m^2 and 0.7 m. The study period was corresponded to the fish culture of tilapia in the others ponds of Blondey. The pond without fish (PWF) was selected in order to assess the colonization of this pond by aquatic macroinvertebrates.

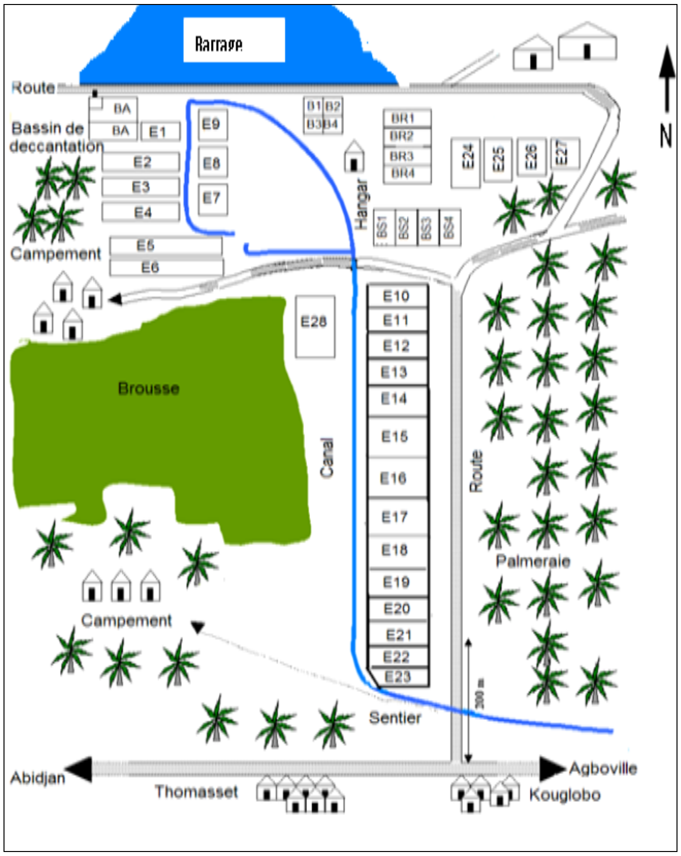

Fig 1: Location of study area

2.2 Data Collection

In fishpond, aquatic macroinvertebrates samplings were undertaken monthly during two periods. The first period: from October 2016to December 2016 corresponding to the juvenil stage which cover the three first month (P1; P2; P3) of the fish culture and the second period: from January 2017 to June 2017 corresponding to the adult stage (G1; G2; G3; G4; G5; G6) in the selected fishpond (PWF). 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 the selected fishpond, in fatter meadow, nine baskets were used according to the device (Figure 2A).The baskets were immersed in the pond by the nylon rope the 1st October 2016. Samples were taken by removing monthly three 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. During the adult stage, eighteen baskets were used (Figure 2B). The same method was used for baskets removing and samples collecting. In the laboratory, specimens were sorted and identified under a binocular magnifying glass (Olympus SZ 40) to the lowest possible taxonomic level by means of the keys in Dejoux *et al.* (1981) [10]; Day *et al.* (2002 ; 2003) [6, 7]; De Moor *et al.* (2003 a, b) [8, 9]; Stals & De Moor (2007) [28]; Tachet *et al.* (2010) [30]. At each sampling period, before macroinvertebrates 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.

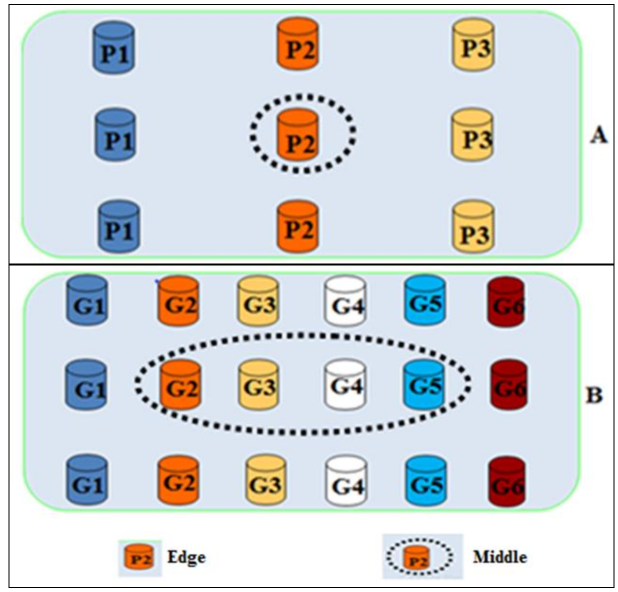

Fig 2: Disposition of artificial substrats during Juvenil stage (A) and Adult stage (B) (P, G = Substrats)

2.3 Data analysis

Macroinvertebrates diversity and structure were described through taxonomic composition and rarefied taxonomic, Shannon-Weaver diversity index (H') (Quinn & Hickey, 1990) [25], Pielou eveness index (Pielou, 1969) [24] (E). The abundance was also analysed and abundance. Shannon-Weaver diversity index was used to assess taxa diversity of macroinvertebrates. 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) [23] for the R 3.0.2 freeware (R Core Team, 2013) [26]. Aquatic macroinvertebrates abundance was obtained by counting all individuals per taxon and expressing the results as numbers per sample. 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 of $p < 0.05$ was considered.

A Canonical Correspondence Analysis (CCA) was carried out using the R package (R Core Team, 2013) [26] to assess the main relationships between environmental variables and functional feeding groups of aquatic macroinvertebrates. This analysis was computed with the Ade4 package (Chessel *et al*., 2004) [5] for the R 3.0.2 freeware.

The functional feeding groups of macroinvertebrates were determined using the classification of Tachet *et al*., (2010) [30]. According to those authors, (1) Detritivores feeding on coarse and fine particulate organic matter, (2) Grazers feeding on algae or phytoplankton, (3) Carnivores preying zooplankton and other animals, (4) Filters using microscopic resources from water column and (5) Omnivores utilizing resources from two or more of the above mentioned trophic groups.

3. Results

3.1 Environmental variables

A summary of the environmental variables collected at the selected fishpond is given in Table 1. The highest value of temperature (31.9 °C) was recorded in adult stage while the lowest value (25.1°C) was recorded in juvenil stage. This parameter was varied significantly (Mann-Whitney test, $p < 0.05$) from juvenil stage (27.33) to adult stage (28.4). Regarding the pH, the highest value (8.7) was obtained in juvenil stage and the lowest value (4.61) was registered in adult stage. The pH was varied significantly (Mann-Whitney test, $p < 0.05$) from juvenil stage (8.23) to adult stage (4.1). Concerning Dissolved oxygen, the maximum (12.15 $mg.l^{-1}$) was obtained in juvenil stage and the minimum (2.8 $mg.l^{-1}$) was recorded in adult stage. There was a significant variable Mann-Whitney test, $p < 0.05$) from juvenil stage (11.47 $mg.l^{-1}$) to adult stage (4.98 $mg.l^{-1}$). The maximum value of water Conductivity was observed in adult stage (76.2 $µs.cm^{-1}$) and the minimum value (23.5 $µs.cm^{-1}$) was recorded in juvenil stage. This parameter was varied significantly (Mann-Whitney test, $p < 0.05$) from juvenil stage (31.36 $µs.cm^{-1}$) to adult stage (63.35 $µs.cm^{-1}$). Considering transparency, the highest value (32cm) was recorded in juvenil stage while the lowest value (17 cm) was obtained in adult stage. This parameter was varied significantly (Mann-Whitney test, $p < 0.05$) from juvenil stage (29.8 cm) to adult stage (20.41 cm).

Table 1: Summary of physico-chemical parameters at the two study periods in fishpond of Blondey (Côte d'Ivoire) (letters (a, b) on the mean values of the same line show the difference between study periods, Mann-Whitney test).

Parameters		Juvenil stage	Adult stage
Temperature (°C)	Min	25.1	26.2
	Med	27.33 [a]	28.4 [b]
	Max	31.9	31.9
pH	Min	7.4	4.61
	Med	8.23 [a]	4.1 [b]
	Max	8.7	5.49
Dissolved oxygen (mg/l)	Min	10.2	2.8
	Med	11.47 [a]	4.98 [b]
	Max	12.15	5.75
Conductivity (µs/cm)	Min	23.5	47
	Med	31.36 [a]	63.35 [b]
	Max	42.6	76.2
Transparency (cm)	Min	27.3	17
	Med	29.8 [a]	20.41 [b]
	Max	32	25

3.2 Taxonomic richness, abundance and composition

The fishpond was flooded in October 2016. The survey of aquatic macroinvertebrates started immediately at the end of this month. The number of taxa increased from the start (October 2016) of juvenil stage (7 taxa) to the end (December 2016) of this stage (14 taxa). The abundance increased (16 – 313 individuals) also from October 2016 (16 individuals) to december 2016 (313 individuals) during this period (Figure 3 A). Concerning the diversity, it's increased during juvenil stage. The course of Shannon-Weaver rised from october (1, 45) to december (1, 66) and the Eveness rised also from October (0, 62) to december (0, 74) (Figure 3 B). On the adult stage, the abundance decreased from january 2017 (601 individuals) to april 2017 (130 individuals) and then it's increased until june 2017 (361 individuals). The number of taxa decreased also from january 2017 (15 taxa) to may 2017 (9 taxa) and this parameter rised again in june 2017 (10 taxa) (Figure 4 A). The diversity was high in february 2017 and low in april 2017. The highest values of Shannon-Weaver and Eveness were registered in february 2017 (1, 90 and 0, 74) and the lowest values of these parameters were obtained in april 2017 (1, 36 and 0, 57) (Figure 4 B). But, there were no significant variations of Shannon-Weaver, evenness, abundance and rarefied taxonomic richness between the two growths stages (Figure 5) (Mann-Whitney test, P > 0.05).

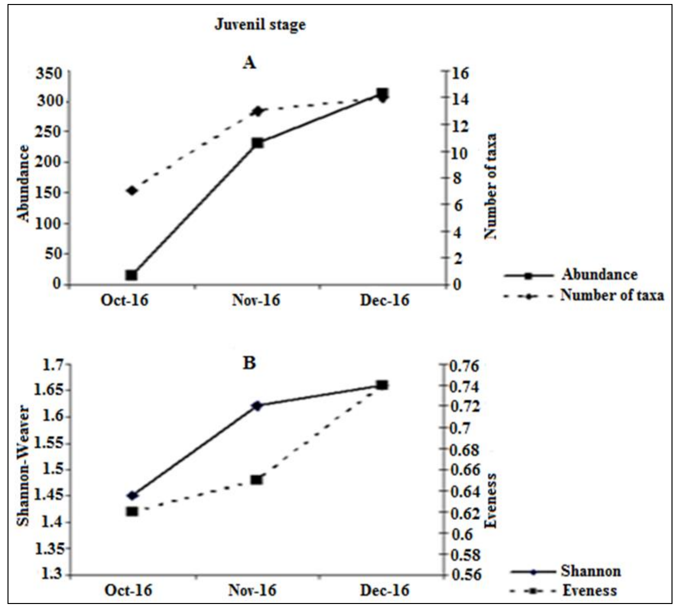

Fig 3: The courses of the biotic parameters on the juvenil stage in year 2016 (A= The course of the abundance and the number of taxa; B = The course of the Shannon-Weaver and the Eveness).

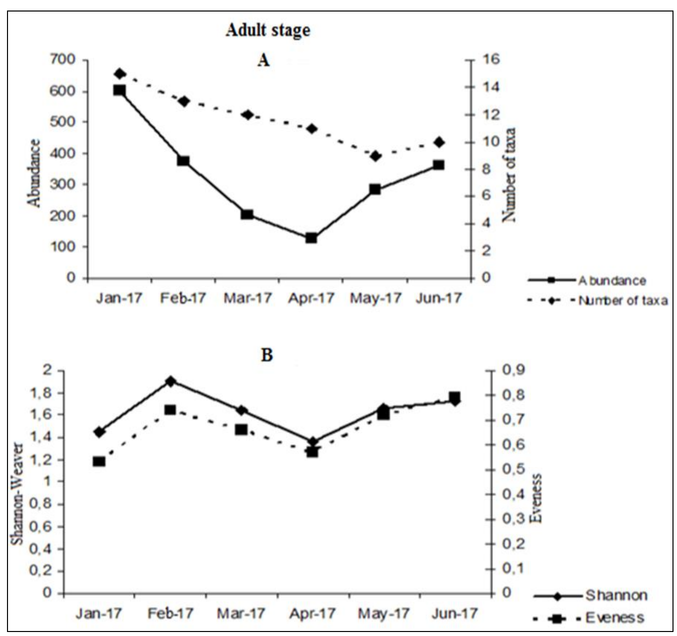

Fig 4: The courses of the biotic parameters on the adult stage in year 2017 (A= The course of the abundance and the number of taxa; B = The course of the Shannon-Weaver and the Eveness).

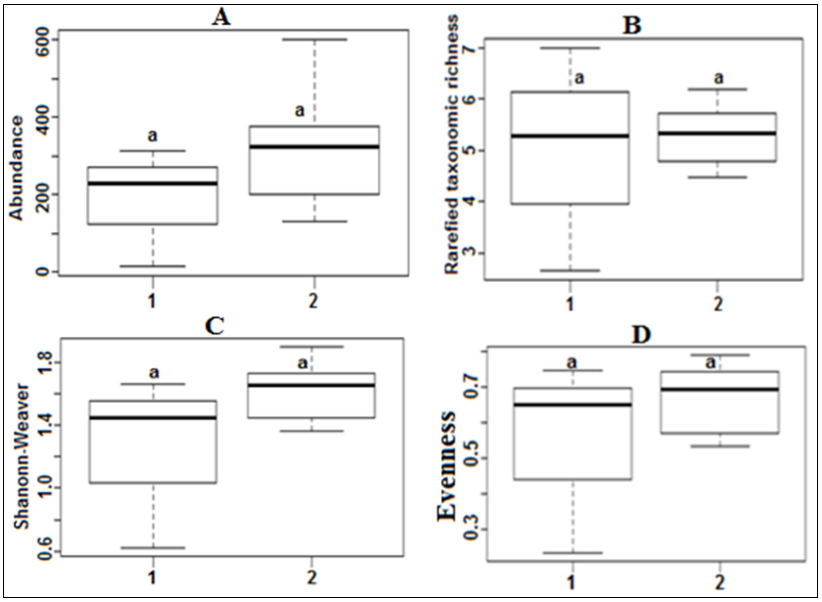

Fig 5: Box-plots showing variations in Abundance (A); Rarefied taxonomic richness (B); Shannon-Weaver (C) and Evenness (D) between the two sampling periods (1 = Juvenil stage; 2 = Adult stage) of fish breeding in a fishpond of Blondey (Letter a on the box-plot revealed no significant variations between clusters (Mann-Whitney, $P > 0.05$).

In total, 32 aquatic macroinvertebrates taxa were recorded, distributed among 18 families, 8 orders and 3 class belonging to Insecta (30 taxa; 93.75% of total richness), Acheta and Gasteropoda (one taxa each over; 3.12%) (Table 2). The taxa abundance varied from 560 individuals (juvenil stage) to 1980 dividuals (adult stage) (Figure 6). Aquatic communities abundance were dominated by Insecta during the two periods: juvenil stage (750 individuals) and adult stage (1250 individuals) (Figure 7). However, *Melanoides tuberculata* (Gasteropoda) and *Glossiphonia* sp. (Acheta) were recorded at all sampling time (Table 2) with high abundance at adult stage respectively (300 and 250 individuals) (Figure 7). Conversely, Insecta taxa such as *Tramea transmarina*, *Trithemis dorsalis* (Libellulidae), *Dytiscus* sp., *Amphiops* sp. (Coleoptera) and *Epheron* sp. (Polymitarcyidae) were present only at juvenil stage. But adult stage was caracterised by *Paragomphus* sp.(Gomphidae), *Caenomedea* sp., (Caenidae), *Micronecta* sp. (Corixidae), *Nilodorum brevipalpis*, *Chironomus imicola*, *Cryptochironomus* sp., *Polypedilum abyssiniae* (Chironomidae) and *Ablabesmyia dusoleili* (Tanypodinae) (Table 2). Moreover, the same abundance almost of Acheta was recorded at the edge (55 individuals) and middle (65 individuals) of fishpond. About Gasteropoda, the high abundance was obtained at the middle (205 individuals) of fishpond while Insecta were mainly collected at edge (1700 individuals) (Figure 8).

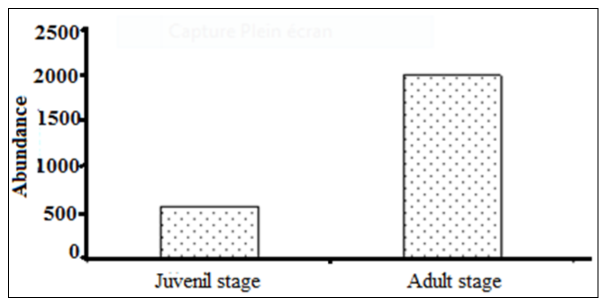

Fig 6: Abundance of aquatic macro invertebrates at the two study periods In fishpond of Blondey (Côte d'Ivoire).

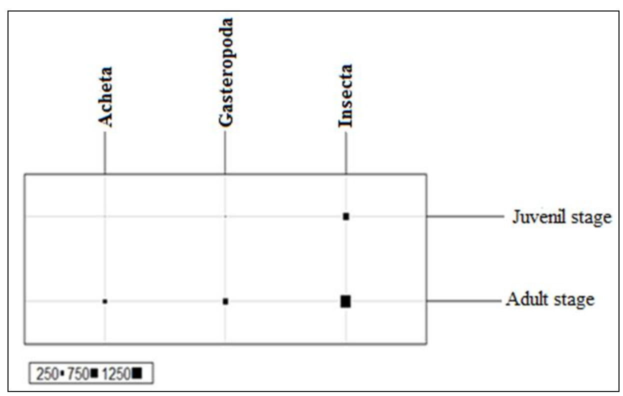

Fig 7: Abundance of aquatic macro invertebrates class at the two study periods in fishpond of Blondey; Juvenil stage ; Adult stage.

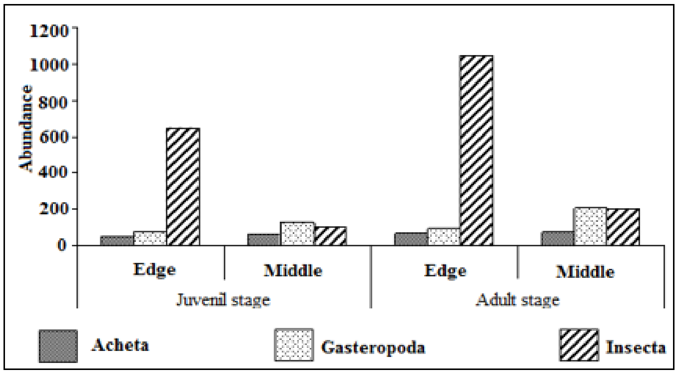

Fig 8: Spatial variation of abundance of aquatic macro invertebrates between the edge and middle in fishpond of Blondey (Côte d'Ivoire).

3.3 Functional feeding groups

A total of five feeding groups were identified (Predator, detritivore, filter, grazer and omnivore). On the juvenil stage, predators were dominated (87, 5%) in October 2016 and there were no detritivore and filter in the organisms sampled. In November 2016, the proportion of organism predators decreased (8, 94%) and the proportion of omnivores increased (87, 22%). We observed also the appearance of filters and detritivore. In December 2016, all the functional feeding groups were registered and increased except omnivores that decreased (51, 93%) (Figure 9 A). On the adult stage, omnivores were presents in January and February 2017 and then, they declined. It's the same for filters which were observed the three first months and disappeared after. The grazers appeared in February 2017, increased and dominated (53, 85%) the functional feeding groups in April 2017. The omnivores and detritivores were presents with the high dominated of detritivores during the adult stage (Figure 9 B).

Typical representatives of predators are taxa *Glossiphonia* sp., *Macrodiplaxcora*, *Bradinopyga* sp., *Ceriagrion* sp., *Dytiscus* sp.; of detritivores are taxa *Caenomedea* sp., *Micronecta* sp., *Nilodorum brevibucca*, *Chironomus imicola;* of omnivores is taxa *Setodes* sp.; of graers is taxa *Melanoïdes tuberculata* and of filter are taxa *Povilla adusta and Epheron sp.* (Table 2).

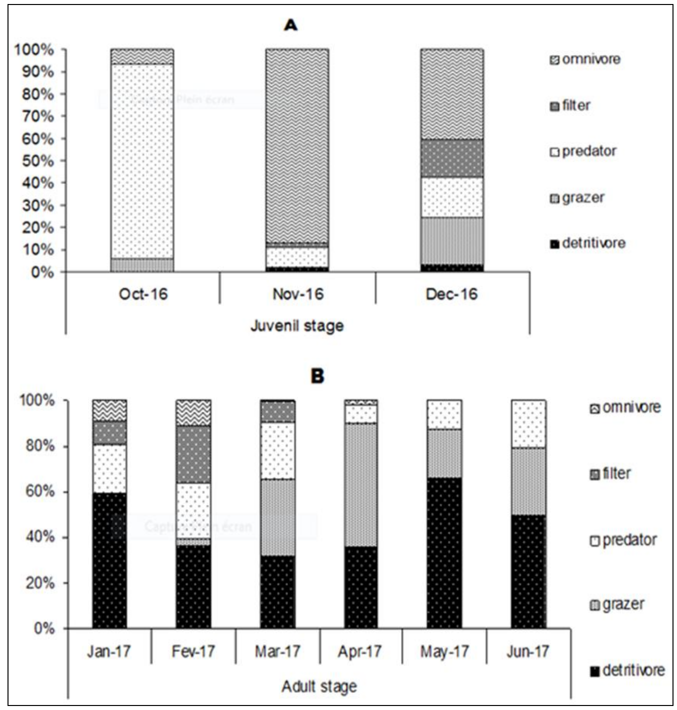

Fig 9: Relative abundance of aquatic macro invertebrates feeding groups on both fish growth stages (A = juvenil stage; B = adult stage).

Table 2: The recorded taxa of aquatic macro invertebrates at the sampling fishpond of Blondey (Southeast Côte d'Ivoire) (1= Detritivore; 2= Grazer; 3= Predator; 4= Filter; 5= Omnivore).

Class	Orders	Familly	Taxons	Acro	Juvenil stage			Adult stage					
					P 1	P 2	P 3	G 1	G 2	G 3	G 4	G 5	G 6
Acheta	Rhynchobdelliformes	Glossiphoniidae	*Glossiphonia* sp. [3]	Gloss	x	x	x	x	x	x	x	x	x
Gasteropoda	Basommatophora	Thiaridae	*Melanoides tuberculata* [2]	Meltu	x	x	x	x	x	x	x	x	x
Insecta	Odonata	Libellulidae	*Macrodiplax cora* [3]	Macroc	x			x					
			Bradinopyga sp. [3]	Brad	x			x	x	x			x
			Zyxomma petiolatum [3]	Zyxo		x	x	x	x				
			Tramea transmarina [3]	Tratra		x	x						
			Trithemis dorsalis [3]	Tridor		x	x						
		Coenagrionidae	*Pseudagrion* sp. [3]	Pseu		x	x	x				x	x
			Ceriagrion sp. [3]	Ceria	x								
		Gomphidae	*Paragomphus* sp. [3]	Parag					x	x			x
	Coléoptera	Dytiscidae	*Dytiscus* sp. [3]	Dytis	x	x	x						
		Hydrophilidae	*Amphiops* sp. [1]	Amp		x	x						
	Trichoptera	Leptoceridae	*Setodes* sp.[5]	Seto	x	x	x	x	x	x	x		
	Ephemeroptera	Polymitarcyidae	*Povilla adusta* [4]	Poad		x	x	x	x	x			
			Epheron sp. [4]	Exeu		x	x						
		Baetidae	*Centroptilum* sp. [1]	Cent		x	x	x	x	x	x	x	
		Caenidae	*Caenomedea* sp. [1]	Caeno					x	x	x	x	
	Héteroptera	Naucoridae	*Naucoris* sp. [3]	Nau		x							
			Macrocoris flavicollis [3]	Macrof		x		x					
		Belostomidae	*Diplonychus* sp. [3]	Diplo			x	x					
		Notonectidae	*Anisops sardea* [3]	Aniss				x	x			x	
		Corixidae	*Micronecta* sp. [1]	Micro				x		x	x		
		Gerridae	*Eurymetra* sp. [3]	Eury					x				

3.4 Relationships between environmental variables and aquatic macroinvertebrates Functional grouping

The results of Canonical Correspondence analysis revealed that the relationships between aquatic macroinvertebrates feeding groups and their habitat conditions follow mainly the first two axis (Figure 10). These two axis accounted for 77 % of the total variance. Dissolved oxygen, Tansparency and pH were negatively correlated to axis 1. High values of these parameters were recorded in juvenil stage (P1, P2, P3). These samples were characterized by the abundance of Omnivore. Conductivity and Temperature were positively correlated to this axis. High values of these parameters were obtained in adult stage (G4, G5, G6, G7, G8, G9). These samples were characterized by the abundance of filter and grazer. Precisely, the samples (G6, G7, G8, G9) were characterized only by Grazer. According to axis 2, Transparency, pH and Temperature were negatively correlated. High values of Transparency and pH, were recorded in sample (P1). Conversely, conductivity and Dissolved oxygen were positively correlated to this axis. High values of Dissolved oxygen were recorded in adult stage (G6, G7, G8, G9). These samples were characterized by the abundance of grazer.

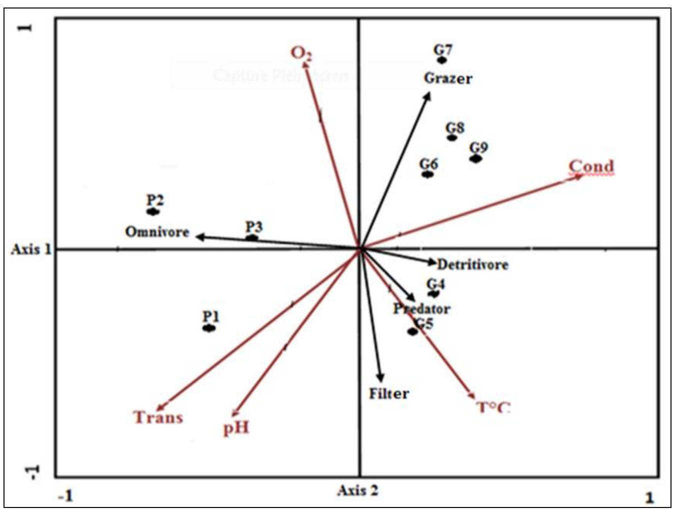

Fig 10: Canonical correspondence analysis triplot showing Functional grouping of aquatic macro invertebrates and sampling months (P = Juvenil stage ; G = Adult stage ; 1 - 9 = sampling month) of Juvenil stage and Adult stage in relation to environmental variables in fishpond selected of fish farm of Blondey (Côte d'Ivoire) (Cond = Conductivity; Trans = Transparency; T°C = Temperature; O2 = Dissolved oxygen).

4. Discussion

This survey revealed that the number of aquatic macroinvertebrate taxa (32) recorded in the selected fishpond of Blondey is low when compared with stuties from Ivorian fishponds and Štěpánekfishpond (Czech Republic).This difference in taxonomic richness was probably due to the number and the size of fishponds sampled. Indeed, 79 species were collected in five fish farm ponds (Banco, Layo, Azaguié, Anyama I and Anyama II) in Southern, Côte d'Ivoire (Yapo *et al*., 2017) [36], and 45 species in three fishponds of Blondey, Côte d'Ivoire (Soro *et al*., 2018) [27]. Sychra & Adamek (2011) [29] recorded 99 taxa in big Štěpánekfishpond (2.2 ha) compared to Blondey fishponds which are more small (450 m^2). Conversely, this taxonomic richness (32) is high compared with the diversity of other Ivorian fishponds. Indeed, 25 taxa were obtained in three fishponds of Natiokobadara (Korhogo) in Northern Côte d'Ivoire (Edia, 2013) [13]. This difference in taxonomic richness was probably due to the sampling methods or sampling tools. Edia (2013) [13] collected aquatic insects in three fishponds by mean of hand net (mesh size: 250µm). In the present study, several artificial substrates were used to trap aquatic macroinvertebrates in a fishpond of Blondey. The number of taxa, the abundance and the diversity increased constantly during juvenile stage. This could be explained by the high values of pH, dissolved oxygen and transparency during this period. This observation corroborated the results of Yapo *et al*. (2014) [33] in five fish farm in Southern, Côte d'Ivoire. Then, the taxonomic richness and diversity decreased in adult stage and this could be the result of high values of temperature and conductivity and could mainly due to the acid water and the lowest value of dissolved oxygen during this period. Concerning abundance, insecta class was dominated during the two periods. This result could be explained by the rapid reproduction cycle and the number of eggs layed or also due to the absence of predator (fishes) (Edia, 2013) [13]. Acheta and Gasteropoda were recorded at all sampling time. These taxa were permanent. This observation could be explained by the resistance of their eggs or cocoons (Brown *et al*., 1997). The high abundance of Trichoptera was recorded at juvenil stage because these taxa preferred good life conditions (Edia *et al*., 2007) [14] regarding to the high values of dissolved oxygen during this period. Inversely, Diptera abundance, was high in adult stage. This observation could be due to the high resistance of this taxa to the bad life conditions regarding to the lowest values of dissolved oxygen at this period. The similar results were observed by Soro *et al*. (2018) [27] in three fishponds of Blondey. Spatial variation showed that, insecta were mostly recorded at littoral zone (edge).The presence of macrophytes in the littoral zone serve both as living space and as laying area for insecta (Sychra & Adamek, 2011) [29]. The high depth and the substrate mainly constituted by mud in central part of the fishpond could be explained the dominance of gasteropoda.

Regarding to functional feeding groups, the predators appeared and dominated firstly, followed by the omnivore (such as *Setodes* sp.) which become the most abundant at the end of juvenil stage. This observation could be due at first, to the permanent taxa such as *Glossiphonia* sp. and *Melanoïdes tuberculata* and then to the high adaptation capacity of omnivore to the available food in the habitat. According to adult stage, detritivore was the most abundance feeding group. The predominance of detritivore could be due to the available of organic matter come from the death of some individuals and the decreasing of dissolved oxygen which can caused the disappearance of no resistant species and replaced by more resistant species such as Chironomidae (*Nilodorum brevipalpis*, *Chironomus imicola*, *Cryptochironomus* sp., *Polypedilum abyssiniae*). In this study, the pattern distribution of functional feeding groups according to environmental variables indicates that omnivores (*Setodes* sp.) were associated with the high values of Dissolved oxygen, Tansparency and pH. In southern Côte d'Ivoire, Yapo *et al*.

(2013) [33] found significant relationships between species composition and pH, temperature, and dissolved oxygen in five fish farm located in the southern Côte d'Ivoire. A similar result was observed by Ogbeibu (2001) who recorded a significant positive correlation between density and water temperature in temporary pond in Okomu Forest Reserve. Conversely, filter and grazer were most influenced by high values of conductivity and temperature. This could be explained by the abundance of phytoplankton in the fishpond.

5. Conclusion

The present study reports 32 aquatic macroinvertebrates taxa in the selected fishpond. The taxonomic richness, abundance and diversity increase constantly during juvenil stage. However, these parameters observed some heterogeneity in their evolution in adult stage. Both growth stages were colonized rapidly by aquatic macroinvertebrates, shortly after the initial flooding. Different predominances in functional feeding groups of aquatic macroinvertebrates were identified between juvenil stage and adult stage. The omnivore dominated the abundance in juvenil stage while detritivore were most abundant in adult stage. About abiotic factors contribution, dissolved oxygen, transparency and pH influenced positively omnivore. However, grazers and filters were very influenced positively by respectively conductivity and temperature. Concerning abundance, rarefied taxonomic richness, Shannon-Weaver and Evenness, Mann-Whitney test revealed no significant variations between juvenil stage and adult stage.

6. Acknowledgments

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