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Original Article

Influence of micro-habitats on the distribution of macroinvertebrates in the Ziga Reservoir, Burkina Faso, West Africa

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Abstract: In this work, we assessed micro-habitat's influence on the distribution of macroinvertebrates in lake Ziga in Burkina Faso from July to December 2016. The water quality variables were measured *in situ* and the macroinvertebrates were collected with a hand net. The organisms were identified to the lower taxonomic resolution as possible. The results show that the temperature is globally warm, characteristic of tropical area, with a good oxygen content and pH close to neutral. We found five micro-habitats, mainly dominated by fine substrates (32.5%) and aquatic plants (25.83%). The stone, roots and dead woods represented less than 20%. In total, 3,773 individuals of macroinvertebrates were collected. These individuals belong to 33 taxa and three classes. The insects class is the most abundant (88.22%) and the most diversified (24 taxa, 72.72%). The highest taxonomic richness is observed in aquatic plants and root zones. The diversity and density of the macroinvertebrate community varies according to micro-habitats but not according to the size of their surface area. The results showed that coleopterans and hemipterans were strongly and positively correlated to transparency and conductivity (adjusted r>60%, $P<0.05$). In the local area, the results showed that macroinvertebrates' diversity and distribution are more linked to habitat availability. Our findings reveal a good habitat condition of the lake, and can be served as reference site and hostpot of aquatic biodiversity in the area.

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Introduction

The effects of anthropogenic activities and climate change are increasing threats to water resources (Younes-Baraillé et al., 2005; Atique et al., 2020a; Hara et al., 2020). These pressures negatively affect water quality and decrease aquatic organism biodiversity (Younes-Baraillé et al., 2005; Agbohessi et al., 2012; Atique and An, 2020). The preservation of aquatic ecosystems necessarily depends on their excellent management. Traditionally, water quality assessment actions have been focused on the measurement of physicochemical parameters (Atique et al., 2020b). Nowadays, the use of biological indicators is a key element of the water resources management policies in many countries (Moog et al., 1999; Haque et al., 2020; Tampo et al., 2020). A biological description provides a holistic view of the state of an ecosystem, as biological communities reflect environmental conditions over time and in space (Reyjol et al., 2012).

Macroinvertebrate communities are the most frequently used to assess the integrity of aquatic ecosystems (Barbour et al., 1999; Clarke et al., 2002; Kaboré et al., 2016a). The use of macroinvertebrates in bioindication has several advantages. Macroinvertebrate communities reflect in their structure any modifications, even temporary of the environment (Kaboré et al., 2016a). They are an essential link in the aquatic ecosystem's trophic chain and have a long-life cycle (Moisan and Pelletier, 2008). A significant change in their community structure will inevitably impact the aquatic fauna

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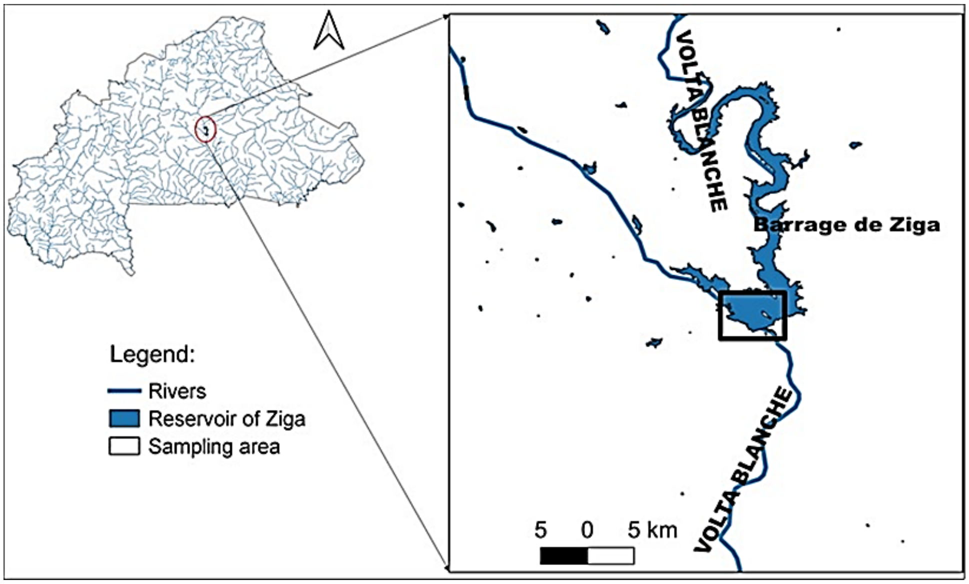

Figure 1. Study site with framed sampling area.

(Tachet et al., 2006; Touzin, 2008).

In Burkina Faso, several studies have examined the diversity and ecology of macroinvertebrates (Guenda, 1986; Kabré et al., 2002; Sanogo et al., 2014; Kaboré et al., 2016a). These authors have demonstrated that the freshwater ecosystem in Burkina Faso harbors the highest diversity of macroinvertebrates composed of insects, the most dominant, Crustaceans, Annelids and Molluscs (Ouédraogo et al., 2015; Kaboré et al., 2016b, c). To analyze changes in the macroinvertebrate population due to human disturbance, all micro-habitats must be taken into account when sampling (Metzeling et al., 2003, Touzin, 2008). In Burkina Faso, few studies have been focused on the impact of micro-habitats in the distribution of macroinvertebrates (Kaboré et al., 2016c). Therefore, this study aims to analyze micro-habitat diversity's influence on the spatial distribution of macroinvertebrates downstream of the Ziga reservoir in Burkina Faso. The specific objectives are to (1) determine the disversity of macroinvertebrates in Ziga reservoir, (2) analyze the impact of habitats on the macroinvertebrates distribution's, and (3) explore the relationship between the physicochemical variables and the macroinvertebrate taxa's.

Materials and Methods

Study area: Burkina Faso is a dry Sahelian country with several reservoirs as the central stocking waters. With a surface of 8 872.5 ha and a volume of 208 million m^3 in the flood period, the reservoir of Ziga (Fig. 1) is one of the biggest in Burkina Faso. It is located between longitude 0 °49'W and latitude 12°37'N, in the middle course of Nakambé basin, which is heavily impaired by human activities (Melcher et al., 2012). It was built in 1998 on the "Volta Blanche" river to provide drinking water to the local population and the country's capital Ouagadougou. With an increasing scarcity of surface water due to the lower rainfall in recent years, Ziga dam lake is subjected by activities such as agriculture using fertilizers and pesticides, livestock, washing and bathing, mainly downstream.

Environmental data collection: The micro-habitats were characterized according to Moog (2007) and Kaboré et al. (2016a). For this study, five micro-habitats were determined: Dead Wood (D-W) habitats dominated by dead leaves and woods; Aquatic Plants (A-P), the portion of habitats dominated by aquatic plants such as macrophytes (e.g. *Nymphaea, Eichhornia,* Reeds); Fine Substrates (F-S) refers to bottom sediments; Root Zones (R-Z), habitats dominated by tree roots, and stones Area (S-A), the habitats where rocks and/or big pebbles are dominants. In each micro-habitat, the following keys physicochemical variables, including temperature, pH, electrical conductivity and dissolved oxygen were measured *in-situ* between 9 and 11 am using a portable multi-parameter probe (HANNA Instrument, HI9829). The transparency and water depth were measured using a Secchi disk and tri-weighted measuring tape. Each parameter was taken monthly for six months, from July to December 2016. The physicochemical variables were measured before the macroinvertebrates sampling.

Macroinvertebrates sampling: The macroinvertebrates were sampled using a hand net (25*25 cm^2 of aperture and a mesh size of 500 µm). Per month, a total of 20 sample units were taken in each micro-habitat. For sampling in practice, aquatic plants and roots are well shaken inside the hand net to collect any hanging organisms. The surface of the rocks was scraped with a brush and then dragged into the hand net. Where possible, stones were moved to capture any organisms that might be underneath. In the fine substrates, the bottom sediment was stirred with the hand or foot to dislodge the organisms and capture them with the net. The dead woods were taken with the hand and their surface was scraped with a brush and dragged into the hand net. After the collection, the content of the net is spilled in a bucket, then thoroughly washed and stripped of large debris such as pieces of wood, large pebbles and leaves. The samples were kept per micro-habitat with ethanol (70%) in plastic pots, then transported in an icebox to the laboratory. Before sorting out the organisms, samples were sieved and the animals were sorted with the naked eye and under to a binocular microscope. Finally, all organisms were identified to the lowest taxonomic level as possible using taxonomic manuals and keys (Durand and Lévêque, 1981; Tachet et al., 2010) and enumerated.

Data analysis: To visualize the variation of physicochemical variables in micro-habitats, box plots were used. The richness and abundance of macroinvertebrate taxa were calculated. Then, the common diversity indices, which provide more information about community composition, rarity and commonness of species in a community were used. Thus, the Shannon-Wiener index (H') (Shannon and Wiener, 1949) and Equitability (Piélou, 1969) were calculated in each micro-habitat using respectively formulas (1) and (2).

$$H' = -\sum((Ni\ /\ N)\ x\ ln\ (Ni\ /\ N))\ (1)$$

Where Ni is the number of individuals of a given species and N: total number of individuals.

$$E\ =\ H'/\ Hmax\ =\ H'\ /\ Log2\ S\ \ (2)$$

Where S is a number of taxa observed. For the density calculation, we used a log transform following the formula.

$$\left(\boldsymbol{D}\left(\frac{\boldsymbol{ind.}}{\boldsymbol{m2}}\right)\right) = \mathbf{log_{10}}\left(\frac{\boldsymbol{Total\ Number\ of\ animals}}{\boldsymbol{Area\ of\ samling\ units}}\right)\ (3)$$

The non-parametric Kruskal-Wallis test was used to test the significances of physicochemical variables and macroinvertebrate diversity in micro-habitats. To explore the influence of environmental variables on macroinvertebrates, the Redundancy Analysis (RDA) (Van den Wollenberg, 1977) were performed with software CANOCO for Window (version 4.5).

Results

Variation in physicochemical variables: In some micro-habitats, the temperature is globally warm (general mean >25°C), characteristic of tropical area, with a good oxygen content and pH close to neutral (Fig. 2). In the Figure 2b, the minimum value of temperature (19.6°C) was found in dead woods (average = 20.3±0.7, P = 0.003) and roots (average=25.54±3.43), and the maximum value (32.4°C) was recorded in fine substrates (average = 26.93±4.06). The minimum and maximum values (2.8-8.09 mg/L) of the dissolved oxygen were reported in aquatic plants (average = 5.66±1.82, Fig. 2d). The minimum value (7 cm) of water transparency and the maximum value (34 cm) were also reported in aquatic plants while the high mean was recorded in the coarse substrate habitats (average = 12.06 cm, P = 0.005, Fig. 2e). The minimum value (6.08) of the pH were found in fine substrates and root habitats, and the maximum value (8.07) in roots (Fig. 2a). The lowest mean (6.22±0.10, P = 0.002) was recorded in the dead woods. The minimum value (41 µS/cm) of the conductivity is recorded in roots (average = 80.12±25.02, P = 0.007) while the maximum value

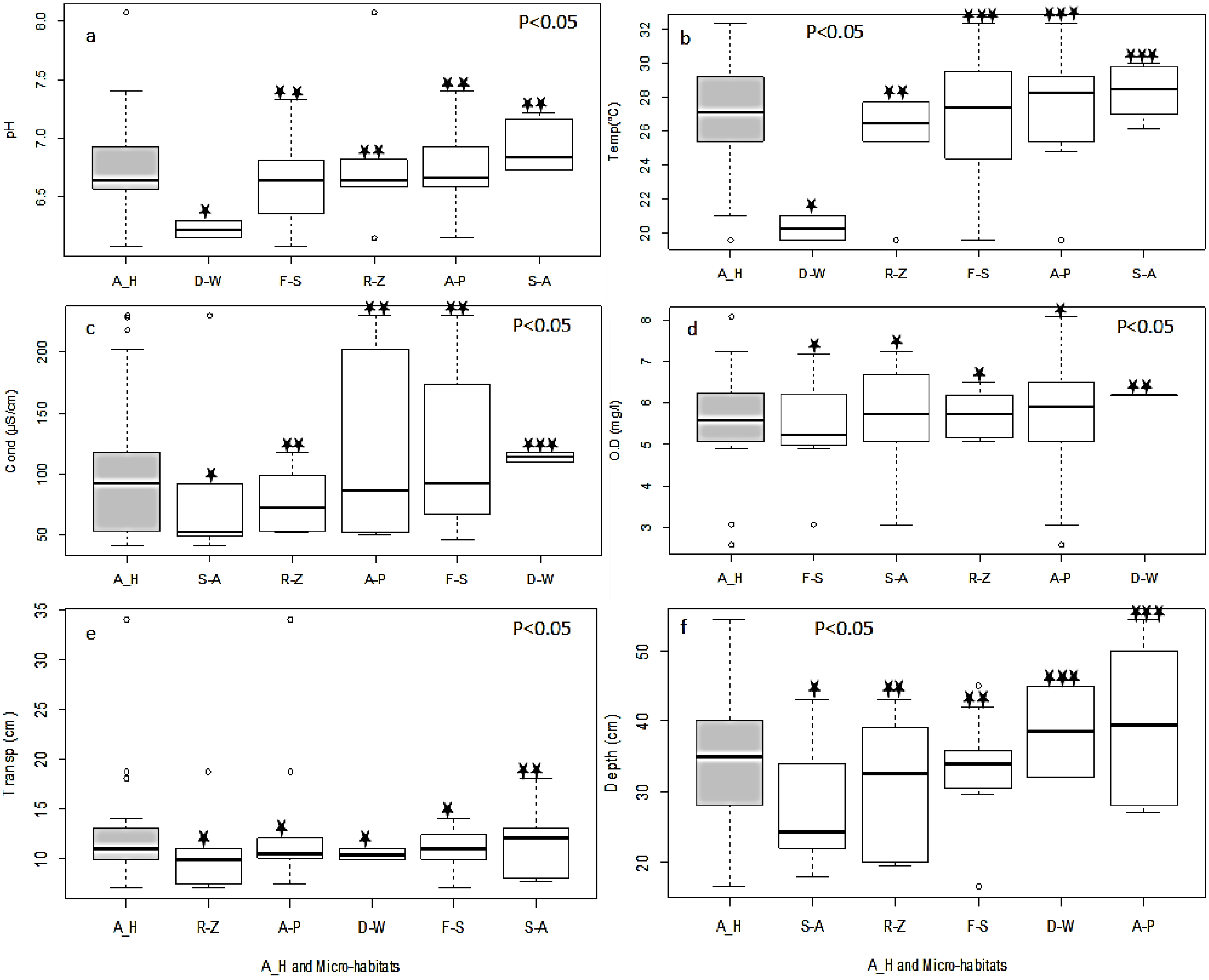

Figure 2. Physico-chemical variables in the micro-habitats. (a) pH, (b) temperature, (c) Conductivity, (d) dissolved oxygen; (e) Transparency and (f) depth. Legend: The number of stars indicates the difference; A _ H = All Habitat; A-P= Aquatic Plants; Cond=Electrical Conductivity; D-W = Dead woods; F-S= Fine substrates; O.D= Dissolved Oxygen; Temp=Temperature; Trans=Transparency; R-Z= Root Zones; S-A =Stone Area. Median value is shown in each box; vertical bars correspond to the minimum and maximum values; the ends of the box indicate the 25th and the 75th quartiles.

(230 µS/cm) was reported in aquatic plants and coarse substrates (averages =113.66±70.35; 109.23±67.87, respectively; Fig. 2c). The aquatic plants have the widest ranges for pH, conductivity and dissolved oxygen.

Taxonomic composition and abundance of macro-invertebrates: In total, 3,773 individuals of macroinvertebrate were collected and all belong to 33 taxa, 10 orders and five classes (Table 1). We found that the insects (72.72% of the total taxonomic diversity) are the most dominant group, with 7 orders and 24 taxa. They are follows by the Molluscs (12%) and the Annelids and Crustceans are the less represented (<10%).

Influence of micro-habitats on the macro-invertebrate's distribution: In the study area, the five micro-habitats selected were mainly dominated by fine substrates (32.5%), aquatic plants (25.83%), followed by coarse substrates (19.58%), roots (16.67%) and dead wood habitats (Fig. 3). The macroinvertebrates structures are mainly influenced by the micro-habitats types. Indeed, the highest

Table 1. Occurrence of macroinvertebrates in the micro-habitats (Note: *= presence).

Phylum	Class	Order	Taxa	D-W	A-P	F-S	R-Z	S-A
Arthropoda	Insects	Coleoptera	Dytiscidae	*	*	*	*	*
			Gyrinidae		*		*	
			Hydrophilidae	*	*	*	*	*
		Diptera	*Bezzia* (Kieffer, 1924)	*		*		
			Chaoborus (Lichtenstein,1800)		*	*	*	
			Chironomidae	*	*	*	*	*
			Culicidae			*	*	*
			Psychodidae			*		
			Simuliidae		*	*	*	*
			Chrysops (Meigen, 1803)		*	*	*	*
		Ephemeroptera	Baetidae	*	*	*	*	*
			Caenomedea (Thew, 1960)	*	*	*	*	*
		Hemiptera	Belostomatidae	*	*	*	*	*
			Micronecta (Kirkadly, 1897)		*	*	*	*
			Gerridae		*			
			Nepidae		*	*	*	
			Notonecta (Linnaeus, 1758)	*	*	*	*	
			Veliidae		*		*	*
		Odonata	*Anax* (Selys, 1872)		*	*	*	*
			Coenagrionidae		*	*	*	*
			Gomphidae	*	*	*	*	*
			Libellulidae	*	*	*	*	*
		Trichoptera	Hydropsychidae		*		*	*
			Leptoceridae		*		*	*
	Crustaceans	Decapoda	*Caridina Africana* (Kingsley, 1882)		*	*	*	
			Gecarcinicidae		*	*	*	*
			Macrobranchium dux (Lenz, 1910*)*			*		*
Molluscs	Gasteropoda	Mesogasteropoda	Ampullaridae		*	*		
			Bellamya unicolor (Olivier, 1804)		*	*	*	
		Basommatophora	*Biomphalaria* (Preston, 1910)		*		*	
	Bivalva	Unionoida	Irridinidae					
Annelids	Clitellata	Arynchobdellida	Hirudinae				*	*
			Haplotaxidae		*	*	*	*
Total			**33**	**10**	**27**	**25**	**27**	**21**

taxonomic richness (more than 25 taxa) was found in plants, root and coarse substrates habitats (Fig. 3a), while the lowest taxonomic diversity (8) was reported in the dead woods ($P<0.05$). We identified 8 common taxa (Dysticidae, Hydrophilidae, Chironomidae, Baetidae, Caenidae (Caenomedea), Belostomatidae, Gomphidae, Libellulidae) in the five micro-habitats. Gerridae and Psychodidae were found only in aquatic plants and fine substrates, respectively (Table 1). The results showed that the Shannon diversity index follows the same trend as taxonomic diversity (Fig. 3). In contrast, the low value (0.64 bits) of Piélou equitability was recorded in the fine substrates (Fig. 3d). The highest density was found in the aquatic

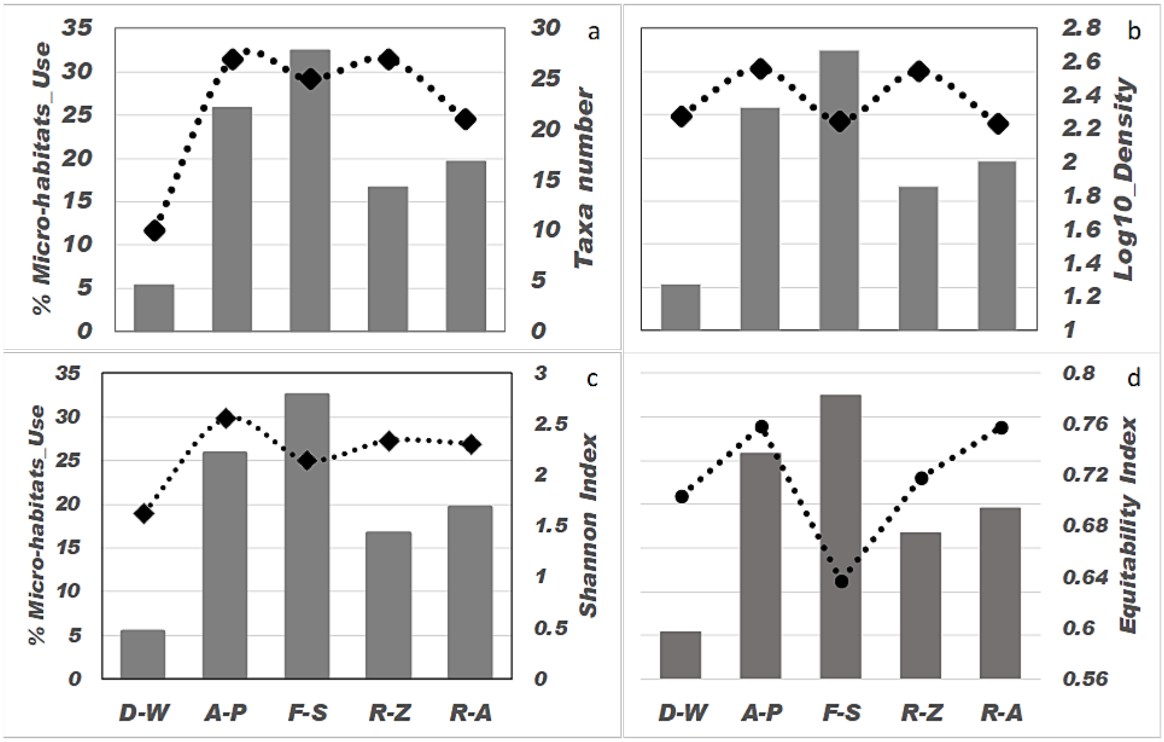

Figure 3. Influence of micro-habitat on the macroinvertebrates distribution. (a) Number of taxa, (b) log10 of the mean density, (c) Shannon index and (d) Equitability index; the histogram indicates the percentage of micro-habitat available and the curve indicates the index.

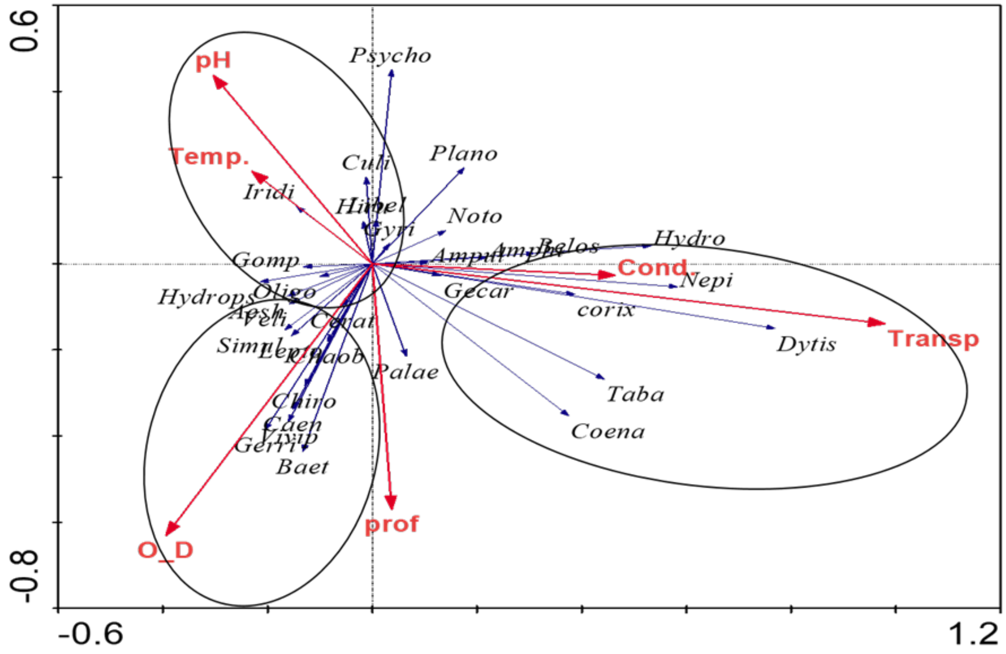

Figure 4. Redundancy analysis (RDA) of macroinvertebrates taxa and environmental variables. Legend : [Aesh = Aeshnidae ; Aty = Atyidae ; Baet = Baetidae ; Cerato= Ceratopogonidae ; Culi = Culicidae ; Coena = Coenagrionidae ; Gyr = Gyrinidae ; Chloro = Chlorolestidae ; Lepto = Leptoceridae ; Hydrops = Hydropsychidae ; Iridi = Iridinidae ; Veli = Veliidae ; Noto = Notonectidae ; Calopt = Calopterigidae ; Ger = Gerridae ; Caeni = Caenidae ; Simuli = Simuliidae ; Hydrom = Hydrometridae ; Chiro = Chironomidae ; Libel = Lebellulidae ; Gomph = Gomphidae ; Taba = Tabanidae ; Chaobo = Chaoboridae ; Nepi = Nepidae ; Gecar = Gecarcinicidae ; Belos = Belostomatidae ; Hiru = Hirudinidae ; Oligo = Oligochaetae ; Corix = Corixidae ; Dytis = Dytiscidae ; pH = potentiel-Hydrogen ; Transp = Transparence ; O. D = Dissolved Oxygen ; Cond = Conductivity ; Temp. = Temperature ; Prof = Depht]”

plants (363.87 =±21.58 ind/m^2), followed by roots (348±3.22 ind/m^2), dead woods (188.30±4.41 ind/m^2), fine substrates (1746.61 ind/m^2) and stones (168.51 ind/m^2), respectively ($P<0.05$) (Fig. 3b). Our findings revealed that macroinvertebrates community are linked to the aquatic plants, the coarse substrates and roots.

Influence of physicochemical variables on macroinvertebrates: The representativeness of all axes, given by the Monte Carlo test, is significant ($P = 0.02$; F-ratio = 5.131). Axis I is very significant ($P = 0.004$; F-ratio = 6.887) and expresses 62% of the information, Axis II, 23.5%, i.e. a total of 85.5% for both axes. Importantly, the polluo-sensitivity of the taxa is notably remarkable in Figure 4. The taxa such as Dytiscidae, Nepidae, Corixidae are positively and strongly correlated to the transparency and conductivity (r = 0.76) that oppose them to those taxa (Iridinae, Gomphidae and Culicidae) which are positively correlated to pH and temperature (r = 0.63). In opposite, Simulidae, Caenidae and Baetidae are positively and strongly correlated to the dissolve oxygen (r = 0.58).

Discussions

The local taxa assemblages are strongly influenced by habitats quality and complexicity (Allan, 2004; Kaboré et al., 2016c). In this study, we recored diverses micro-habitats mostly dominated by fine sediments, aquatic plants and coarse substrates. The diversity and frequency of micro-habitats can be explained by the sampling period that corresponds to the rainy season. With rainfall, the floods increase and enlarge the ecological niche, which contributes to expanding micro-habitats for macroinvertebrates (Ouéda et al., 2007; Kaboré et al., 2016a). The similar results were obtained by Kaboré et al. (2016a) who have proven a strong relationship between macroinvertebrates and physicochemical variables. The poor water conditions observed in some micro-habitats could be attributed to man-induced activities, such as vegetable farms using fertilizers and pesticides, bathing, washing, and animal pasture. We found evidence of those activities near the study sites.

This study reveals that benthic invertebrates are dominated by the Arthropods community followed by Molluscs and Annelids typical of tropical freshwater ecosystems (Barbour et al., 1999; Edia et al., 2013; Tampo et al., 2015; Kaboré et al., 2016a; Tanon et al., 2020; Bancé et al., 2021). Most macroinvertebrates taxa recorded here are similar to those encountered in previous studies in Burkina Faso (Guenda, 1986; Sanogo et al., 2014; Ouédraogo et al., 2015; Kaboré et al., 2016a, b) that have demonstrated that the lakes ecosystems harbor high diversity of insects. This can be explained by insects' remarkable capacity to adapt to different biotopes even those of extreme conditions (Tachet et al., 2003; Mereta et al., 2011). The results are similar to those reported by several authors in tropical regions (Diomandé et al., 2009; Sanogo et al., 2014; Kaboré et al., 2016; Bancé et al., 2021). Our finfings revealed a high number of taxa (33) compared to those of Kabré et al. (2000) who have idenfied four taxa in Bagré lake. This could be justified by the sampling technique using multi-habitat approche (Camara et al., 2012; Kaboré et al., 2016a). In other hand, the number of taxa found here is lower compared to those of Kaboré et al. (2016c), who have reported 60 taxa. That can be explained by the fact: (1) one site was sampled, and (2) the organisms were mostly identified to families and genera taxonomic resolution.

The diversity of macroinvertebrates increases with habitat conditions and food resources availability. According to these authors (Ouéda et al., 2007; Kaboré et al., 2016a), organic matters contribute to the proliferation of phytoplankton, zooplankton and detritus which improve the food resources and enhance habitat quality for benthic macroinvertebrates. The high number of individuals found in plants and root reinforce our arguments that those habitats enclose an important amount of organic matters (Bournaud and Cogerino, 1986). The abundance of aquatic plants enhances environmental heterogeneity, protects from predators, and reduces competition between species (Gong et al., 2000; Uwadiae, 2013; Kaboré et al., 2016a). For example, dipterans such as Chironomidae deposit their eggs in the plants, which could explain their high density in this micro-habitat (Dejoux, 1977). As well, dead wood by decaying organic matter can serve as supplementary food resources for aquatic organisms. The aquatic vegetations offer protection to rheophilic taxa such as Hydropsychidae, Simuliidae, and filter-feeding larvae that take advantage of organic matter inputs from water. Cummins and Lauff (1969) also demonstrated that the availability of food resources can influence the distribution of macroinvertebrates locally. The sampling area is located in the most threaned basin of Burkina Faso. This could explain the dominance of the tolerant taxa. According to Melcher et al. (2012), Nakambé bassin is the most populated and urbanized area with intense anthropogenic activities (e.g. intense agriculture using pesticides and fertilizers, vegetables farming).

Conclusion

This study we assessed the biotic and abiotic factors that influence the distribution of macroinvertebrates in the lake. The results showed that the physico-chemical variables and habitat types determine strongly the structure of macroinvertebrates community. In our findings, coarse substrares and aquatic plants harbour the highest diversity of macroinvertebrates. The results also showed that the study area is impacted by anthropogenic activities as proven by the dominant of tollerants taxa recorded. The protection of habitats is a fundamental for aquatic biodiversity conservation in West Africa, especially in Burkina Faso were the aquatic ecosystems are ongoing pressures. And the environmental restoration measures may help to mitigate the aquatic habitats degradation and biodiversity declining in the Nakambé basin.

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