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Ecological status of a newly impounded sub-saharan reservoir based on benthic macroinvertebrates community (Burkina Faso, West Africa)

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In West Africa, particularly in Burkina Faso, the aquatic ecosystems are under human pressures. Therefore, for long term management of these ecosystems, the managers need baseline data for regular assessment of ecological health condition. In this regard, the structure of the benthic macroinvertebrate community was investigated and the relationship between the environmental variables and biotic indices of the Samandéni reservoir from January to December 2018, after one-year impoundment was explored. The macroinvertebrates were collected with a hand net (25 × 25 cm^2 coverage area and 500 µm mesh) according to the multi-habitat sampling method. Key environmental variables such as temperature, conductivity, dissolved oxygen, pH and total dissolve solids (TDS) were measured *in situ*. High diversity of macroinvertebrates was reported and thirty-four (34) taxa were determined belonging to eight (8) orders dominated by insects (79.41% of all taxa). Good ecological quality of the reservoir was testified by the presence of several sensitive taxa like Ephemeroptera and Trichoptera. The trends of environmental variables also reflect good habitat conditions. The results revealed a strong and negative relationship between some abiotic variables and biotic indices. The finding of this study is of big importance for sustainable management of the Samandéni Reservoir.

Key words: Burkina Faso, macroinvertebrates, monitoring, reservoir, status.

INTRODUCTION

The key global challenge in the 21st century is to maintain the supply of clean water and other aquatic ecosystem services that are of benefit to human's well-being, without affecting biodiversity and ecosystem processes that reinforce their sustainability (Pawlowsky et al., 2018). The effect of climate changes on hydrological and biological dynamics is poorly documented in developing countries (Taniwaki et al., 2017). Therefore, studies on the health of inland aquatic ecosystems are crucial for each nation which must supply water both qualitatively and quantitatively to meet the increasing demands of local populations. Many authors have demonstrated that monitoring water quality by using biological approaches, especially macroinvertebrates communities has greater advantages compared to physical and chemical approaches (Jun et al., 2012; Nyamsi et al., 2014). While

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physical and chemicals measurement required expensive and specialized equipments, and do not provide long-term predictions of environment changes. But benthic macroinvertebrates are recognized as very good indicators, and are the most commonly used (Nyamsi et al., 2014; Kaboré et al., 2016a, c; Gerami et al., 2016; Arimoro and Muller, 2010). This is due to: (a) their sedentary nature, which facilitates spatial analyses of pollution effects, (b) the sensitivity of many common species are well-documented for different types of pollutants (Myers et al., 2011), and (c) the long life cycles of some species, which make them more cost-effective tools to trace pollution effects over longer periods (Heino and Peckarsky, 2014). Habitats degradation, land uses, hydromodification and water pollution can be monitored by assessing benthic macroinvertebrates community structure, and indicators species (Flores and Zafalara, 2012; Kambwiri et al., 2014; Kaboré et al., 2016a; Patang et al., 2018). A large number of biotic metrics/indices have been developed in different countries (Chi et al., 2017; Borja et al., 2013; Dedieu et al., 2015; USEP, 2018; Tampo et al., 2020). However, in developing countries, and particularly in Western African region, the use of biological organisms for monitoring aquatic ecosystems health is still less documented (Kaboré et al., 2016a; Tanon et al., 2020). In Burkina Faso, few studies have addressed the ecological status of the reservoirs. The studies on macroinvertebrates are those of Guenda (1986), Kaboré (2016) and Kaboré et al. (2016a, 2018) that have assessed riverine ecosystems health, and those of Koblinger and Trauner (2013) and Sanogo et al. (2014) on benthic invertebrates' diversity in standing waters. Kaboré et al. (2016a, 2018), Koblinger and Trauner (2013) and Sanogo et al. (2014) mentioned that macroinvertebrates are good indicators of ecosystem conditions (Reyjol et al., 2012; Selvanayagan and Abril, 2016), because they respond to environment disturbances due to human activities. Burkina Faso's last big reservoir is Samandéni, built in 2017 and classified as a Ramsar site in October 2020 (https://rsis.ramsar.org/ris/2439). The dam and associated wetlands provide water for electricity, agriculture and human consumption, while the sparse population plays a major role in enabling the maintenance of biodiversity levels. The vegetation consists of wooded savannah and open forests, combined with dense semi-deciduous gallery forests with trees of up to 40 m in height. The site hosts internationally threatened tree species like the kosso *Pterocarpus erinaceus* and the mahogany *Afzelia Africana* and *Khaya senegalensis*. It also features a diverse range of mammals, waterbirds, fish and reptiles. Minoungou (2020) recorded 40 species of fish, dominated by seven species (*Sarotherodon galilaeus*, *Coptodon zillii*, *Oreochromis niloticus*, *Marcusenius senegalensis*, *Synodontis schall*, *Schilbe intermedius* and *Brycinus nurse*) (Minougou et al., 2020). Globally threatened mammals such as the Hippo (*Hippopotamus amphibious)* and the African elephant (*Loxodonta Africana)* also feature. The increasing human population downstream of the site, increased spread among local communities of water-related diseases, dispersal of hippopotamus herds, impacts of climate change and the lack of stakeholder consultation in its management and development are among the more urgent threats facing the natural resources in the site (https://rsis.ramsar.org/ris/2439). The sustainability of local socio-economic activities reposes on better management of this important reservoir. The present study aims to provide a first database on his benthic macrofauna, one year after its impoundment. The specific objectives were to: (1) evaluate the composition and diversity of benthic macrofauna in the reservoir and (2) explore the relationship between environmental variables and biotic indices as well as describe ecological status using macroinvertebrate community.

MATERIALS AND METHODS

Study area

In Burkina Faso, the climate is characterized by highly irregular rainfall patterns with marked differences between wet and dry seasons which lead to highly chronic water scarcity and episodes of severe drought. The country relies much on reservoirs to produce food (maize, cereals, fruits, vegetables, fish, meat, etc.) for local and national consumptions and sustain socio-economic development in rural area. Following this, a new reservoir named Samandéni reservoir was created in 2017. This study was undertaken in this reservoir, located in the upper Mouhoun catchment (a sub-catchment of the Volta River), with an area of 20,980 km^2 (DGIRH, 2001). The data were collected from January to December 2018 in five sampling stations (Figure 1): Badoville (11°23'55,90"N; 04°34'41,40"W), Dioufoulma (11°23'00,28"N; 04°37'32,41"W), Sadina (11°26'53,22"N; 04°37'43,20"W), Banzon (11°19'59,83"N; 04°46'00,14''W) and Sikorola (11°25'24,55"N; 04°43'19,22"W). The Badoville and Dioufoulma stations are characterized by low human activities, with natural vegetation in the floodplain (e.g. shrubs and trees) typical to the area. Banzon, Sikorola and Sadina stations are characterized by intense activities, such as crops farming, banana plantation, and livestock in the riparian zone. In order to assess the dynamic of the benthic community in the reservoir, four sampling campaign were conducted from January to December 2018. Unfortunately, Dioufoulma, Banzon and Sikorola stations are prohibited during periods of heavy rain by the authorities for safety reasons.

Water variables measurement

At each sampling station, the key water variables such as pH, temperature (°C), electrical conductivity (µS cm^{-1}), dissolved oxygen (DO) (mg/L) and total dissolved solids (TDS) (ppm) were recorded *in-situ* using a portable multi-parameter device (*Hanna Instrument, HI9829*) between 9 and 11 a.m. Each variable was measured in triplicate at each sampling station. Immediately after water variables measurement, the macroinvertebrates were collected.

Benthic macroinvertebrates sampling

The macroinvertebrates were sampled with a hand net (rectangular

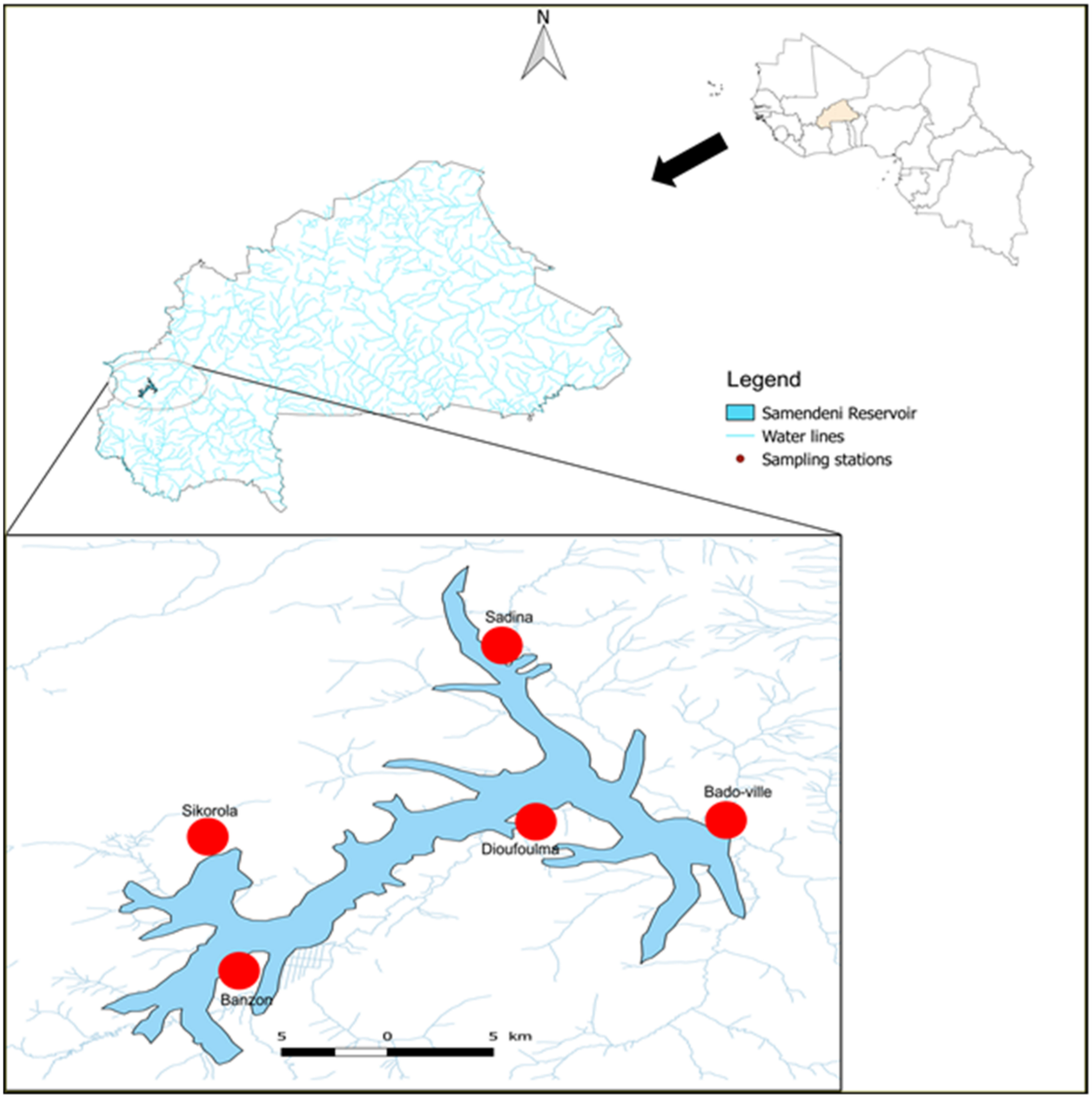

Figure 1. Study area with sampling stations in red dots.

opening: 25 cm x 25 cm, mesh size: 500 µm) according to the multi-habitat sampling approach described in Moog (2007). At each station, a pooled sample, consisting of 20 sampling units was taken from all microhabitats available in proportion to their coverage. The habitats were mainly composed of macrophytes (emerged and submerged plants), sediment (sand, mud, litter) and coarse substrate. Samples were fixed in ethanol (90%), and transported to the laboratory for detailed examination. Prior to sorting out the organisms, samples were sieved and the animals were sorted using a binocular microscope. All taxa were identified to the lowest taxonomic level as possible using taxonomic manuals and keys (Tachet et al., 2003; Moisan and Pelletier, 2008).

Data analysis

The mean and standard deviations, as well as extreme values (minimum and maximum) were calculated for all physico-chemical variables. We used the Kruskall-Wallis test ($p<0.05$) to analyse the variation of physico-chemical variables between sampling stations.

Species occurrences, number of taxa, EOT taxa, relative abundance of some groups (Molluscs, Chironomids, Hemipterans Coleopteran) per station, Shannon-Wiener index (H') and Equitability were estimated to evaluate invertebrates' diversity and abundance. The relative abundance is the percentage of individual particular taxon by total number of all taxa. The Shannon-Wiener

Table 1. Summary statistics of water variables measured in the field for the 5 sampling stations during the study period.

Physicochemical characteristics	All stations (5)		
	Mean	Min	Max
Temp (°C)	25.83 (±2.90)	22.15	33.60
DO (mg/L)	5.68 (±1.18)	4.00	9.00
Cond (µS/cm)	109.69 (±22.20)	50.60	200.00
TDS (ppm)	49.74 (±5.18)	44.00	60.00
pH	7.48 (±0.18)	6.89	7.95

Max= Maximum, Min= Minimum. Value in parentheses indicates the standard deviation.

index (H') (Shannon and Wiener, 1949) and the Equitability (Piélou, 1969), are the common diversity indices which provide information about community composition, rarity and commonness were calculated using respectively formulas (1) and (2).

1) $H' = -\Sigma ((Ni / N) \times \ln (Ni / N)$

where Ni: number of individuals of a given taxa and N: total number of individuals.

2) $E = H' / H \max = H' / \text{Log2}\ S$

where S: number of species observed.

The frequency of occurrence was determined for each taxon following Dajoz (2000): rare (<25%), frequent (25-50%), and very frequent (>50%). To explore relationship between water variables and biotic indices, Spearman correlation was used. Cases of weak correlation (Spearman r <0.5; p> 0.05) were excluded from the final matrix.

Ethical statement

According to the authors, the research was conducted according to ethical standards.

RESULTS

Physico-chemical status of the reservoir

Study stations had slightly warm water temperatures (mean=25.83°C), a neutral pH (mean=7.48), good oxygen contents (mean=5.68 mg/L) and low conductivity (mean=109.69 µS/cm) (Table 1). The highest temperature (27.4°C), pH (7.75) and dissolved oxygen were recorded in Sadina. The highest conductivity (145.33 µS/cm) was found in Sikorola. The Kruskal-Wallis test shows no significant difference (p > 0.05) between the values of pH, temperature, DO and conductivity obtained at the 5 stations.

Taxonomic diversity and occurrence

The Samandéni Reservoir harbor high diversity of macroinvertebrates (Table 2). A total of 34 macro-invertebrate taxa were identified belonging to four classes (Insects, Molluscs, Crustaceans and Annelids), eight (8) orders and 33 families. Insects were the most diversified class with 27 taxa (79.41% of all taxa) followed by the Mollusks (4 taxa). Crustaceans (2 taxa) and Annelids (1 taxa) are the less represented. Eleven taxa (Baetidae, *Caenomedea* sp., *Bezzia* sp., Chironomidae, Coenagrionidae, *Micronecta* sp., *Ranatra linearis*, Dytiscidae, Hydrophillidae, Libellulidae, and *Biomphalaria* sp.) are common to all stations. The high taxonomic diversity (28 and 22 taxa) was found in Bado-ville and Sadina, respectively, while the lowest (14 taxa) in Dioufoulma. Five taxa (*Notonurus* sp., Oligoneuridae, *Ephoron* sp., *Laccotrephes* sp., *Notonecta* sp.) two taxa (*Macrobrachium dux*, Chlorolestidae), one taxon (*Lymnae (Radix) natalensis)* and one taxon (Elmidae) were specifically recorded in Badoville, Sikorola, Sadina, and Banzon, respectively (Table 2).

The Ephemeroptera (Baetidae, *Caenomedea* sp.), Diptera (Chironomidae), Odonata (Coenagrionidae) and Hemiptera *(Micronecta* sp.) were the common taxa (FO>50%) in the reservoir. One taxon of Molluscs (*Biomphalaria* sp.) was very frequent in four stations (Table 2).

Taxa abundances

In total, 2804 individuals of macroinvertebrate were recorded. Overall, the Order of Diptera was the most abundant (28%), followed by Ephemeroptera (25%) and Hemiptera (22%) (Figure 2). In Badoville and Dioufoulma, the Diptera (35.61%) were the most dominant group followed by the Ephemeroptera (29.49%). While in Sadina, the Ephemeroptera (31.48%) were the most abundant group followed by Diptera (22.66%). The results reveal that the Hemiptera and Diptera were well represented in Sikorola and Banzon.

Diversity metrics

Figure 3 showed the variation of metrics (taxa richness, EOT-taxa, % of Chironomidae, % of Molluscs, % of

Table 2. List of benthic macroinvertebrates taxa collected from Samandéni Reservoir during the period of study.

Phylum	Class	Order	Family	Taxa	Bado.	Sadi.	Siko.	Ban.	Diou.
Arthropoda	Crustaceans	Decapoda	Atyidae	*Caridina Africana* Kingsley, 1882	**			**	
			Palaemonidae	*Macrobrachium dux* Lenz, 1910			*		
	Insects	Ephemeroptera	Baetidae	Baetidae	***	***	***	***	***
			Caenidae	*Caenomedea sp.* Thew, 1960	***	***	***	***	***
			Heptageneidae	*Notonurus sp.* Demoulin, 1973	**				
			Oligoneuridae	Oligoneuridae	**				
			Polymitarcyidae	Polymitarcyidae	**				
			Trichorytidae	*Tricorythus sp.* Eaton, 1868	***				
		Trichoptera	Ecnomidae	*Ecnomus sp.* Thomson, 1859	**	**			
		Diptera	Ceratopogonidae	*Bezzia sp*. Kieffer, 1924	***	***	***	*	***
			Chironomidae	Chironomidae	***	***	***	***	***
			Culicidae	Culicidae		**	**	*	
			Tabanidae	*Chrysops* Meigen, 1803	***	**	**	*	
			Psychodidae	Psychodidae				*	
		Hemiptera	Belostomatidae	Belostomatidae	***	***	**	*	
			Coenagrionidae	Coenagrionidae	***	***	***	***	***
			Corixidae	*Micronecta sp.* Kirkadly, 1897	***	***	***	***	***
			Gerridae	Gerridae	**	**	*		
			Naucoridae	Naucoridae	*	**	**		
			Nepidae	*Laccotrephes sp.* Stål, 1866	**				
			Notonectidae	*Notonecta sp.* Linnaeus, 1758	**				
			Ranatridae	*Ranatra linearis* Limnaeus, 1758	**	***	**	*	**
			Veliidae	*Rhagovelia sp.* Mayr, 1865	**	***	***		**
		Coleoptera	Dytiscidae	Dytiscidae	***	***	***	*	***
			Elmidae	Elmidae				*	
			Hydrophilidae	Hydrophilidae	***	***	***	**	***
		Odonata	Chlorolestidae	Chlorolestidae			**		
			Gomphidae	Gomphidae	***	**			**
			Libellulidae	Libellulidae	***	***	***	**	***
Annelids	Clitellata	Arynchobdellida	Hirudinae	Hirudinae	**				**
Molluscs	Gasteropoda	Basommatophora	Thiaridae	Thiaridae	**	**		**	
			Planorbidae	*Biomphalaria sp*	***	***	***	*	***
			Lymnaedae	*Lymnae(Radix) natalensis* Wright, 1966		**			
			Unionidae	Unionidae	**	**			
Total			34	34	28	22	19	18	14

Bado: Badoville; Sadi: Sadina; Siko: Sikorola; Ban: Banzon; Diou: Dioufoulma. ***Very frequent (FO > 50%); **frequent (25% ≤FO ≤50%); *rare occurrence (FO < 25%).

Coleoptera, % of Hemiptera, Shannon-Weiner diversity and Equitability) used to analyse benthic invertebrate's diversity. We found that the indices: total taxa and EOT-taxa, show the same variation. The high values of diversities were found in Badoville and Sadina, while the low values of diversities and EOT-taxa were recorded in Dioufoulma and Banzon (Figure 3a, d). Figure 3b and c show that the percentages of chironomids, molluscs, hemipterans and beetles vary from station to station. In stations where the percentage of Chironomidae is high, that of molluscs is low (Figure 3b). Similarly, in stations where the percentage of hemipterans is high, that of beetles is low (Figure 3c).

Correlations between biological and environmental data

Spearman correlation between metrics and physico-chemical variables (Table 3) indicated that conductivity

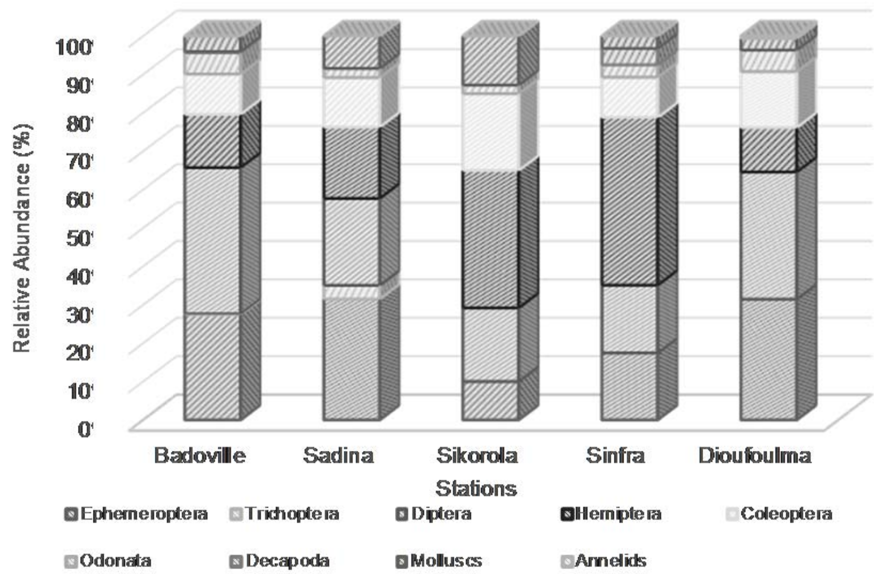

Figure 2. Relative abundance of macroinvertebrate orders encountered in the Samandéni Reservoir.

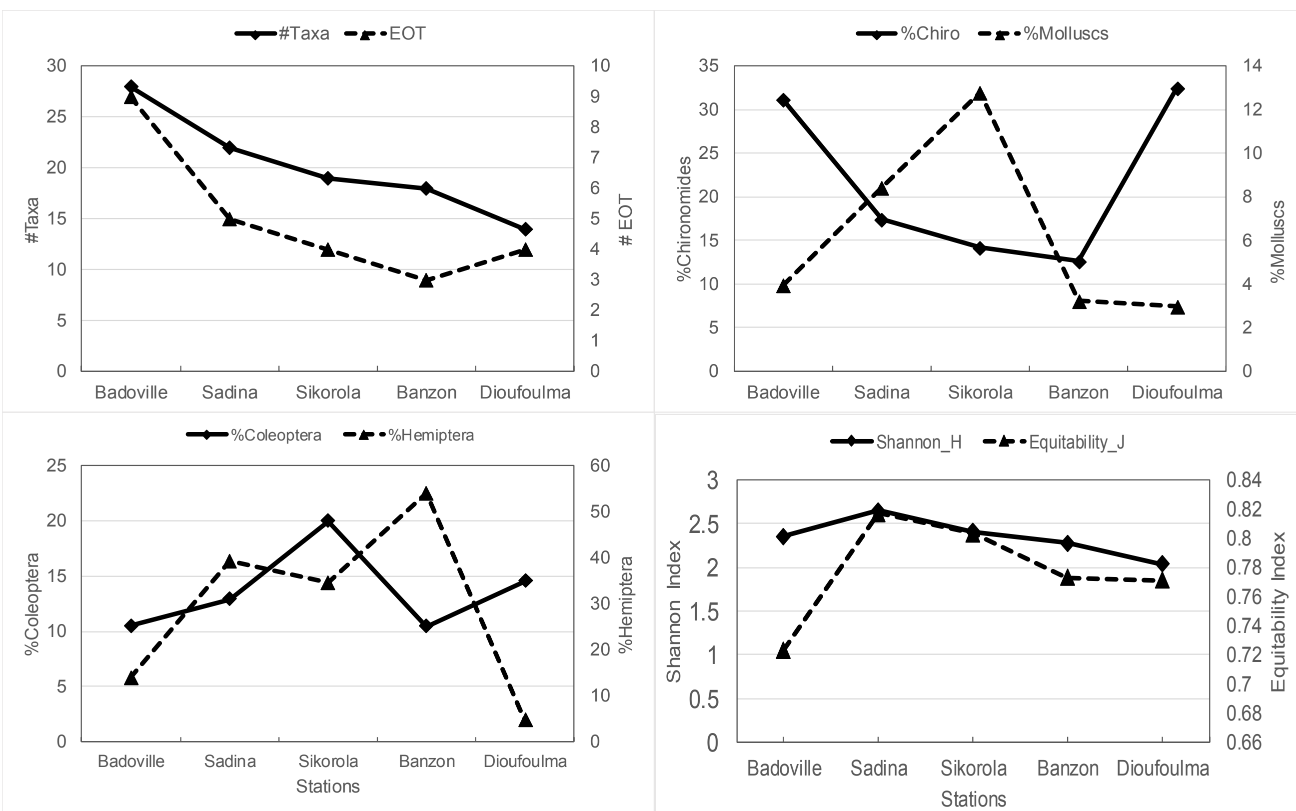

Figure 3. Variation of the biotic indices in the sampling stations.

taxa (Spearman correlation r=-0.97, $p< 0.05$) and total number of taxa (r=-0.90, $p< 0.05$) while water pH was highly and positively correlated to EOT-taxa (r=0.87, $p< 0.05$). The significant positive correlation was also detected between the temperature and hemipterans (r=0.8, $p< 0.05$). We found that chironomids abundances

Table 3. Correlation Matrix of Water Variables and Biological Index marked with an asterisk (*) =statistically significant (p<0.05).

Biological Index / Water Variable	Total Taxa	%Chironomidae	%Molluscs	EOT	%Coleoptera	%Hemiptera	Shannon	Equitability
pH	0.6	0.6		0.87*			0.5	
Temp	0.5	-0.5			-0.6	0.8*	0.6	0.5
OD	0.40							0.6
Cond	-0.90*		-0.5	-0.97*			-0.6	
TDS		0.8*	-0.6			-0.5		

16 Insect taxa not identified to species level. Out of 34 taxa in Table 2, only 15 are identified to species level.

was highly and strongly correlated with EOT- were significantly and positively correlated to total dissolved solids (Table 3).

DISCUSSION

Water quality parameters are key factors that influence the life of living organisms in water bodies (Pardo et al., 2012; Hussain and Pandit, 2012). Other studies have underlined the importance of physical-chemical variables for biomonitoring in tropical streams (Thorne and Williams, 1997; Lakew and Moog, 2015). Indeed, authors have demonstrated that the intense land use in riparian zone can deteriorate the quality of water physical and chemical variables (Kaboré et al., 2018; Meulenbroek et al., 2019). In this study, the values of the main physicochemical variables are similar to those obtained by Kaboré et al. (2018) in the reference sites of Burkina Faso. That can be explained by the fact that the riparian zone of the reservoir is slightly impacted by human activities such as agriculture and livestock, hence the good physical and chemical condition of the Samandéni Reservoir. This data can be used as baseline status data to monitor the quality of reservoir habitat.

The diversity obtained (34 taxa) is higher than that obtained by Sanogo et al. (2014) in three reservoirs located in the same Mouhoun catchment. The high diversity of macroinvertebrates found in the present study can be explained by the habitat heterogeneity and suitable conditions due to lower human pressures in the riparian zone. Our results are similar to those reported by Camara et al. (2012) and Kaboré et al. (2016a), who have demonstrated that areas are created to preserve natural resources and wilde animals. According to Kaboré et al. (2016a), Moog (2007), and Selvanayagam and Abril (2016), the variation of the structure of macroinvertebrate community is influenced by the habitat conditions. Here, the lower diversity observed in Dioufoulma, Banzon and Sikorola could be explained by anthropogenic activities such as vegetable crops farming (e.g. using fertilizers and pesticide) in the riparian areas. In contrast, the good ecological condition of Badoville and Sadina stations can justify the hight diversity recorded here.

Our findings showed that insects are the most abundant. That could be explained by the large ability of this group to survive in different types of habitats (Tachet et al., 2010; Mereta et al., 2011), and can also adapt to many feeding strategies in water colunm. This agrees with previous studies on sub-Saharan areas that have proven that the tropical fresh water, harbors a high diversity of macroinvertebrates dominated by insects (Adandedjan et al., 2011; Edia et al., 2013; Sanogo et al., 2014; Kaboré et al., 2016a; Sirima et al., 2017). The presence of macroinvertebrate groups such as Ephemeroptera, Trichoptera and Odonata, recognized as sensitive to pollution, indicates that the Samandéni Reservoir has good ecological conditions (Wahizatul et al., 2013; Kaboré et al., 2016a, b). Other authors (Suleiman and Abdullahi, 2011; Sharma and Chowdhury, 2011) argued that the range of habitats and water chemistry offers basis for a high diversity of freshwater macroinvertebrates. In the same trend, many studies showed that, key sensitive taxa can decline with a decrease of water quality, which is mainly caused by human activities (Flores and Zafalara, 2012; Elias et al., 2014; Morris et al., 2014). The functional composition of benthic communities is linked to the supply and persistence of particular resources taken up by aquatic food webs and should be responsive to any changes affecting the latter (Merritt and Cummins, 2006). The low electrical conductivity of the reservoir water testifies to its low mineralization due to the weakness of organic matter. The opposite variation in the abundance of Chironomidae and Molluscs may be due to competition between the two groups for habitat and food supply. Indeed, organic matters are used by other Chironomids to build cases. Also, it contributes to improve algae and macrophytes proliferation in water bodies, which constitute an important food resource for mollusks proliferation. In the sites, the variation of the abundances of other macro-invertebrate groups, such as Beetles and Hemiptera reveal that the two groups do not share the same food resources. Thus, according to Kaboré et al. (2016a) and Masese et al. (2014), the Beetles are herbivore-detritivore, while most of Hemipterans are predators. The diversity of taxa sensitive to pollution are parameters most often used to assess the quality of an aquatic environment (Kaboré et al., 2016a; Masese and Raburu, 2017). The same variations observed for the indices: total diversity and EOT taxa in the stations, could be explained by the fact that they reveal the same information on the ecological state of the site. Total-taxa and the EOT index would be more suitable for evaluating the quality of stagnant water than the EPT taxa, which have been recognized as very good indicators of riverine ecosystems integrity (Myers et al., 2011; Kaboré et al., 2016a; Masese and Raburu, 2017; Jerves-Cobo et al., 2017). The absence of plecopterans may be due to the fact that the water in the reservoir is stagnant. The Odonata are considered as important indicators of environmental conditions, as they inhabit both aquatic and terrestrial habitats during their life cycle, and therefore may better reflect disturbance in riparian buffer modification (Goertzen and Suhling, 2013; Oliveira-Junior et al., 2015; Miguel et al., 2015; Monteiro-Júnior et al., 2015). Because the Odonates are predators, according to Stoks and Córdoba-Aguilar (2012) and Nedjwa et al. (2018), their presence can express good diversity of macro-fauna in the water. Here we found also a strong and negative correlation between the electrical conductivity and EOT-taxa. Indeed, the high conductivity is often an indicator of water pollution because it is likely to be affected by different riparian land use types (DeTroyer et al., 2016; Kaboré et al., 2016a, c, 2018; Meulenbroek et al., 2019).

Conclusion

This study provides the first inventory data of macroinvertebrates in Samandéni Reservoir. It harbors the high diversity of macroinvertebrates dominated by insects. We found that EOT-index could be a good indicator of ecological status of standing water bodies, and could be used as monitoring basis tool for the management and conservation of big fisheries ecosystems, particularly in Burkina Faso.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Adandedjan D, Laleye P, Ouattara A, Gourène G (2011). Distribution of Benthic Insect Fauna in a West African Lagoon: The Porto-Novo Lagoon in Benin. Asian Journal of Biological Sciences 4:116-127. https://doi.org/10.3923/ajbs.2011.116.127.

Arimoro FO, Muller WJ (2010). Mayfly (Insecta: Ephemeroptera) community structure as an indicator of the ecological status of a stream in the Niger Delta area of Nigeria. Environmental Monitoring and Assessment 166 (1-4):581-594.

Borja A, Mike EB, Jesper HAC, Ana CG, Jacob CC, João GFD, Anna-Stiina HE, João CMF, João M NF, Heliana TG, Laura UE, María CUA, Nikolaos Z (2013). Good Environmental Status of marine ecosystems: What is it and how do we know when we have attained it? Marine Pollution Bulletin 76(1-2):16-27. http://dx.doi.org/10.1016/j.marpolbul.2013.08.042.

Camara IA, Diomande D, Bony YK, Ouattara A, Franquet E, Gourene G (2012). Diversity assessment of benthic macroinvertebrate communities in Banco National Park (Banco Stream, Côte d'Ivoire), African Journal of Ecology 50: 205-217.

Chi S, Yutian G, Hongjun W, Jinxiu Z, Jun H, Juxiang H, Fangyong D (2017). A pilot macroinvertebrate-based multimetric index (MMI-CS) for assessing the ecological status of the Chishui River basin, China. 2017. Ecological Indicators 83:84–95 http://dx.doi.org/10.1016/j.ecolind.2017.07.045.

Dajoz R (2000). Précis d'écologie, 7 ème edition, Dunod, Paris. 615 pp.

Dedieu N, Clavier S, Vigouroux R, Cerdan P, Céréghino R (2015). A multimetric macroinvertebrate index for the implementation of the european water framework directive in french guiana, east amazonian. River Research and Applications 2015. https://doi.org/10.1002/rra.2874.

DeTroyer N, Mereta ST, Goethals PL, Boets P (2016). Water Quality Assessment of Streams and Wetlands in a Fast Growing East African City. Water 2016 8(4) :123. https://doi.org/10.3390/w8040123.

Direction Générale de l'Hydraulique, Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques (DGIRH) (2001). Etat des lieux des ressources en eau du Burkina Faso et de leur cadre de gestion (version finale). Ouagadougou, Burkina Faso: Rapport. P243.

Edia OE, Bony KY, Konan KF, Ouattara A, Gourène G (2013). Distribution of aquatic insects among four coastal river habitats. Bulletin of Environment, Pharmacology and Life Sciences 2:68-77.

Elias JD, Ijumba JN, Mgaya YD, Mamboya FA (2014). Study on freshwater macroinvertebrates of some Tanzanian rivers as a basis for developing biomonitoring index for assessing pollution in tropical African regions. Journal of Ecosystems 2014 Article ID 985389, 8 pages. https://downloads.hindawi.com/archive/2014/985389.pdf

Flores MJL, Zafaralla MT (2012). Macroinvertebrate composition, diversity and richness in relation to the water quality status of Mananga river, Cebu, Philippines. Philippine Science Letters 5(2):103-113.

Gerami MH, Patimar R, Negarestan H, Jafarian H, Mortazavi MS (2016). Temporal variability in macroinvertebrates diversity patterns and their relation with environmental factors. Journal of Biological Diversity 17(1):36-43.

Guenda W (1996). Etude faunistique, écologique et de la distribution des insectes d'un réseau hydrographique de l'Ouest africain : le Mouhoun (Burkina Faso) ; rapport avec Similium damnosumTheobald, vecteur de l'onchocercose. Thèse d'état, Université Aix Marseille P 260.

Goertzen D, Suhling F (2013). Promoting dragonfly diversity in cities: Major determinants and implications for urban pond design. Journal of Insect Conservation 17(2):399-409.

Hussain Q A, Pandit AK (2012). Macroinvertebrates in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture 4(7):114-123. Available online at http://www.academicjournals.org/IJFA. doi 10.5897/IJFA11.045.

Jerves-Cobo R, Everaert G, Iñiguez-Vela X, Córdova-Vela G, Díaz-Granda C, Cisneros F, Nopens I, Goethals PLM (2017). A Methodology to Model Environmental Preferences of EPT Taxa in the Machangara River Basin (Ecuador). Water 2017 9(3):195.

Jun YC, Won DH, Lee SH, Kong DS, Hwang SJ (2012). A multimetric benthic macroinvertebrate index for the assessment of stream biotic integrity in Korea. International Journal of Environmental Research and Public Health 9:3599-3628.

Kaboré I, Jäch MA, Ouéda A, Moog O, Guenda W, Melcher AH (2016a). Dytiscidae, Noteridae and Hydrophilidae of semi-arid waterbodies in Burkina Faso: species inventory, diversity and ecological notes. Journal of Biodiversity and Environmental Sciences 8(4):1-14. ISSN: 2220-6663 2222-3045.

Kaboré I, Moog O, Alp M, Guenda W, Koblinger T, Mano K, Ouéda A, Ouédraogo R, Trauner D, Melcher AH (2016b). Using macroinvertebrates for ecosystem health assessment in semi-arid streams of Burkina Faso. Hydrobiology 766(1):57-74. https://doi:10.1007/s10750-015-2443-6.

Kaboré I, Ouédraogo I, Tampo L, Ouéda A, Moog O, Guenda W, Melcher A H (2016c). Diversity, composition and dynamic of benthic macroinvertebrate community in semi-arid rivers of Burkina Faso (West Africa). International Journal of Bioliogical and Chemical Sciences 10(4):1542-1561. https://doi:10.1007/s10750-015-2443-6.

Kaboré I (2016). Benthic invertebrate assemblages and assessment of ecological status of water bodies in the Sahelo Soudanian area (Burkina Faso, West Africa); A thesis submitted to the University of Natural Resources and Life Sciences, Vienna Austria for the award of “Doctor rerum naturalium technicarum. Doctor of Natural Resources and Life Sciences. P 246.

Kaboré I, Moog O, Ouéda A, Sendzimir J, Ouédraogo R, Guenda W, Melcher AH (2018). Developing reference criteria for the ecological status of West African rivers. Environmental Monitoring and Assessment 190(1):1-17. https://doi.org/10.1007/s10661-017-6360-1.

Kambwiri AM, Changadeya W, Chimphamba J, Tandwe T (2014). Land Use Impacts on Water Quality of Rivers draining from Mulanje Mountain: A Case of Ruo River in the Southern Malawi. Malawi Journal of Science and Technology 10(1).

Koblinger T, Trauner D (2013). Benthic invertebrate assemblages in water bodies of Burkina Faso. Master Thesis, University of Natural Resources and Life Sciences, Vienna, Austria. P. 156

Lakew A, Moog O (2015). A multimetric index based on benthic macroinvertebrates for assessing the ecological status of streams and rivers in central and southeast highlands of Ethiopia. Hydrobiologia 751:229-242.

Masese F, Kitaka N, Kipkemboi J, Gettel GM, Irvine K, McClain ME (2014). Macroinvertebrate functional feeding groups in Kenyan highland streams: evidence for a diverse shredder guild, Freshwater Science 33(2):435-450 https://doi.org/10.1086/675681.

Masese FO, Raburu PO (2017). Improving the performance of the EPT Index to accommodate multiple stressors in Afrotropical streams. Africain Journal of Aquatic Science 42(3):219-233.

Meulenbroek P, Stranzl S, Ouéda A, Sendzimir J, Mano K, Kabore I, Ouedraogo R, Melcher A (2019). Fish Communities, Habitat Use, and Human Pressures in the Upper Volta Basin, Burkina Faso, West Africa. Sustainability 11(19):5444.

Mereta ST, Boets P, Bayih AA, Malu A, Ephrem Z, Sisay A, Endale H, Yitbarek M, Jemal A, Meester LD, Goethals PLM (2011). Analysis of environmental factors determining the abundance and diversity of macroinvertebrate taxa in natural Wetlands of Southwest Ethiopia. Ecological Informatics 7:52-61. http://dx.doi:10.1016/j.ecoinf.2011.11.005.

Merritt RW, Cummins KW (2006). Trophic relationships. pp 585-609 in Hauer FR, Lamberti GA, eds. Methods in Stream Ecology, 2nd ed. Academic Press, San Diego.

Miguel GM, Francisco A, Marcos R, Isabel SP (2015). Macroalgal Composition Determines the Structure of Benthic Assemblages Colonizing Fragmented Habitats. PloS ONE 10;10(11):e0142289. journals.plos.org ; https://doi.org/10.1371/journal.pone.0142289.

Minoungou M (2020). Caractéristiques physico-chimiques et piscicoles du lac de barrage de Samandeni avant l’ouverture de la pêche (Burkina Faso). Mémoire de Master, Université Joseph KI-ZERBO. p 78

Minoungou M, Ouedraogo R, Da N, Oueda A (2020). Relation longueur-poids et facteur de condition de sept espèces de poisson du réservoir de Samandeni avant son ouverture à la pêche (Burkina Faso). Journal of Applied Biosciences 151:15559-15572.

Moisan J et Pelletier L (2008). Guide de surveillance biologique basée sur les Macroinvertébrés benthiques d’eau douce du Québec – Cours d’eau peu profonds à substrat grossier. Direction du suivi de l’état de l’environnement, ministère du développement durable, de l’environnement et des parcs, ISBN: 978-2-550-53591-1. P86.

Monteiro-Júnior CS, Juen L, Hamada N (2015). Analysis of urban impacts on aquatic habitats in the central Amazonbasin: adult odonates as bioindicators of environmental quality. Ecological Indicators 48:303-11.

Moog O (2007). Deliverable 8 – Part 1. Manual on Pro-rata Multi-habitat-sampling of Benthic Invertebrates from Wadeable Rivers in the HKH-Region. BOKU – University of Natural Resources and Applied Life Sciences, Vienna. P28 www.assess-hkh.at.

Morris EK, Caruso T, Buscot F, Fischer M, Hancock C, Maier TS, Meiners T, Muller C, Obermaier E, Prati D, Socher SA, Sonnemann I, Waschke N, Wubet T, Wurst S and Rillig MC (2014). Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. Ecology and Evolution 4(18):3514-3524. http://doi.org/10.1002/ece3.1155.

Myers LW, Kondratieff BC, Mihuc TB, Ruiter DE (2011). The mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) of the Adirondack Park (New York State). Transaction of the American Entomological Society 137:63-140.

Nedjwa B, Amin K, Nabila B, Moussa H, Rassim K (2018). Niche partitioning at emergence of two sympatric top-predator dragonflies, Anax imperator and A. parthenope (Odonata: Aeshnidae), Annales de la Société entomologique de France (N.S.), DOI: 10.1080/00379271.2018.1426492.

Nyamsi TNL, Foto MS, Zébazé TSH, Onana FM, Adandedjan D, Tchakonté S, Yémélé TC, Koji E and Njiné T (2014). Indice Multimétrique des Macroinvertébrés Benthiques Yaoundéens (IMMY) Pour L'évaluation Biologique de la Qualité des Eaux de Cours D'eau de la Région du Centre Sud Forestier du Cameroun. European Journal of Scientific Research123(4):412-430. ISSN 1450-216X / 1450-202X.

Oliveira-Junior JMB, Shimano Y, Gardner TA, Hughes RM, Marco Junior P, Juen L (2015). Neotropical dragonflies (Insecta: Odonata) as indicators of ecological condition of small streams in the eastern Amazon. Austral Ecology 40:733-744.

Pardo I, Gómez-Rodríguez C, Wasson JG, Owen R, de Bund W, Kelly M, Bennett C, Birk S, Buffagni A, Erba S, Mengin N, Murray-Bligh J, Ofenböeck GI (2012). The European reference condition concept: A scientific and technical approach to identify minimally-impacted river ecosystems. Science of the Total Environment 420:33-42.

Patang F, Soegianto A, Hariyanto S (2018). Benthic macroinvertebrates diversity as bioindicator of water quality of some rivers in East Kalimantan, Indonesia. International Journal of Ecology 2018: 5129421. DOI: 10.1155/2018/5129421.

Pawlowski J, Kelly-Quinn M, Altermatt F, Apothéloz-Perret-Gentil L, Pedro B, Boggero A, Borja A, Bouchez A, Cordier T, Domaizon I, Maria JF, Ana FF, Riccardo F, Wolfram G, Jelger H, Berry van der H, Iwan Jones J, Sagova-Mareckova M, Moritz C, Jose B, Piggott JJ, Maurizio P, Rimet F, Rinkevich B, Sousa-Santos C, Specchia V, Trobajo R, Vasselon V, Vitecek S, Zimmerman J, Weigand A, Leese F, Kahlert M (2018). The future of biotic indices in the ecogenomic era: Integrating (e)DNA metabarcoding in biological assessment of aquatic ecosystems. Science of The Total Environment 637(638):1295-310.

Piélou EC (1969). An Introduction to Mathematical Ecology, Wiley, New York.

Reyjol Y, Spyratos V, Basilico L (2012). Bioindication: des outils pour évaluer l'état écologique des milieux aquatiques - Perspectives en vue du 2ème cycle DCE - Eaux Roux de surface continentales. Paris: Les rencontres de l'ONEMA. P 56.

Sanogo S, Kabre TJA, Cecchi P (2014). Spatial–temporal dynamics of population structure for macroinvertebrates taxa in a continuum dam – effluent – river in irrigated system. Volta Basin (Burkina Faso). The International Journal of Agricultural Policy and Research 2:203-214.

Selvanayagam M, Abril R (2016). Use of benthic macroinvertebrates as a biological indicator in assessing water quality of River Puyo, Puyo, Pastaza, Ecuador. American Journal of Life Sciences 4(1):1-12. https://doi: 10.11648/j.ajls.20160401.11.

Shannon CE, Weaver W (1949). The Mathematical Theory of Communication. University of Illinois Press, Urbana.

Sharma KK, Chowdhary S (2011). Macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi (J&K). International Journal of Biodiversity and Conservation 3(5):167-174.

Sirima D, Ouéda A, Ouédraogo I, Ouédraogo I, Guenda W (2017). Distribution des Chironomidae (diptères) dans deux réservoirs urbains (Ouagadougou, Burkina Faso). Annal de l'Université Ouaga 1 Pr Joseph KI-ZERBO– Série C vol 013, Juillet 2017.

Stoks R, Córdoba-Aguilar A (2012). Evolutionary ecology of Odonata: a complex life cycle perspective. Annual Review of Entomology 57:249-265.

Suleiman K, Abdullahi IL (2011). Biological assessment of water quality: A study of Challawa river water in Kano, Nigeria. Bayero Journal of Pure and Applied Sciences 4(2):121-127.

Tachet P, Richoux H, Bournaud P, Usseglio-Polatera M (2003). Invertébrés d'eau douce : Systématique, biologie, écologie édition CNRS Paris P 588.

Tachet H, Richoux P, Bournaud M, Usseglio-Polatera P (2010). Invertébrés d'eau douce : systématique, biologie, écologie - CNRS éditions Paris.

Tampo L, Lazar MI, Kaboré I, Ouéda A, Akpataku KV, Djaneye-Boundjou G, Bawa LM, Lazar G, Guenda W (2020). A multimetric index for assessment of aquatic ecosystem health based on macroinvertebrates for the Zio river basin in Togo. Limnologica https://doi.org/10.1016/j.limno.2020.125783.

Taniwaki RH, Piggott JJ, Ferraz SFB, Christoph DM (2017). Climate change and multiple stressors in small tropical streams. Hydrobiology 793:41-53.

Tanon YD, Camara IA, Kouadio NK, Doumbia L, Ouattara A et Diomandé D (2020). Taxonomic Diversity and Structure of Benthic Macroinvertebrates of Taabo Lake (Basin of Bandama; Ivory Coast). Journal of Environmental Science Studies 3(1):1-14 2020 ISSN 2591-779X E-ISSN 2630-4821.

Thorne RSTJ, Williams WP (1997). The response of benthic macroinvertebrates to pollution in developing countries: a multimetric system of bioassessment. Freshwater Biology 37(3):671-686.

United States Environmental Protection Agency (USEP) (2018). Basic Information on Water Quality Criteria, 2018, https://www.epa.gov/wqc/basic-information-water-quality-criteria#aquatic

Wahizatul AA, Zazali C, Abdul RAR, Nurul'Izzah AG (2013). A new invasive coconut pest in Malaysia: the red palm weevil (Curculionidae: Rhynchophorus ferrugineus). Planter 89(1043):97-110 ref.25.