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SEASONAL CHANGES IN THE ABUNDANCE OF BENTHIC MACROINVERTEBRATES & PHYSICO-CHEMICAL CONDITION OF MOUSSA STREAM BIDA, NIGERIA

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ABSTRACT

Seasonal changes in the abundance of benthic macroinvertebrates and physico-chemical condition of Moussa Stream, Bida Nigeria, were studied monthly from January to August 2017. Macroinvertebrates were sampled using modified kick sampling techniques. Three different sampling stations were selected along the course of the Stream. The results from the stream showed that water temperature (24.9-27.5^{0}C), Depth (14.7-45.8cm), Flow velocity (0.14-0.23m/s), Biochemical oxygen demand (2.0-7.0mg/L), pH (6.33-8.6), Conductivity (20-63µ/cm), Alkalinity (8-30mg/L), Turbidity (61-285NTU), Nitrate (0.87-3.85mg/L) and Phosphate (0.31-1.01mg/L) were within the maximum permissible limit (WHO, SON) except Dissolved oxygen (3.1-10mg/L). Most of the parameters investigated with the exception of depth and flow velocity showed no significant difference ($p>0.05$) among all the sampling stations. Temperature, depth and flow velocity showed no significant differences with season. pH, DO, BOD_5, Turbidity, Conductivity, Alkalinity, Nitrate, and Phosphate were significantly higher during wet season. A total of 471 individuals from 30 species and 20 families of invertebrates were recorded. The overall macroinvertebrates recorded from station 1, 2 and 3 were 166(35.24%), 149(31.63%) and 156(33.12%). Overall, there was significant difference ($P<0.05$) in number of individuals among the sampling stations. The abundance according to the Orders revealed that Coleopterans, Odonata and Hemipterans were the most common groups encountered. Ephemeroptera Diptera, Mollusca and Oligochaeta were sparingly found in all stations. The percentage and total number of individuals of macroinvertebrates recorded during the study period shows 67.09% (316 individuals) in dry season and the remaining 32.90% (155 individuals) were recorded in rainy season. CCA result correlated positively between species abundances and measured environmental variables. Low density of pollution sensitive macro invertebrates groups and the deteriorating water quality were implications of pollution stress caused by anthropogenic activities.

Key words: seasonal changes, macroinvertebrates, stream, Bida.

INTRODUCTION

Benthic macroinvertebrates constitute fundamental aspect of aquatic biotic community, their capacity to reveal diverse degrees of relationship within the aquatic ecosystem shows their importance in both economy and ecology (Keke *et al.,* 2017). Benthic macroinvertebrates have limited mobility and can stay in an area for sometimes without moving away easily, the type of the macroinvertebrates found in an area can be used as indicator of the status of the water quality of that environment at that location in a particular time (Arimoro and Keke, 2016). The physical and chemical characteristics of water bodies and their immediate biotypes are one of the major factors in determining the diversity, abundance and distribution of macroinvertebrates (Edegbene *et. al*., 2015). Water quality of an aquatic environment is evaluated due to land used pattern and other anthropogenic activities across the reach of the River (Edegbene *et. al*., 2015). In assessing the aquatic ecosystem, macroinvertebrates usually have several advantage when used as bioindicators compared to other aquatic organism, they are influenced by anthropogenic stress and natural factors such as, water temperature, light level, water chemistry, food resources and habitat structure; these factors present seasonal variations in communities due to changes in species related to life history strategy (Chi *et al.,* 2017).

Seasonal changes are the most important factor in temporal variability of macroinvertebrates communities. Temporal changes in invertebrate communities can result from seasonal dry-wet cycles and associated physicochemical changes. In the dry season, habitat area and types are often reduced (from rifles and pools to drying pools), resulting in lower taxa richness or diversity in some systems (Garcia-Roger *et al*., 2011). In other systems, mechanisms are less straightforward. The abundance of stream invertebrates is known to be influenced by environmental conditions such as hydraulic stress, temperature and water chemistry (Linares *et al*., 2013). Seasonal variation is important to determine ecological changes in the tropics and rainfall distribution patterns have great impact on both the water chemistry as well as the population dynamics of the fauna (Linares *et al.,* 2013). Changes in characteristics, habitat and environmental resources of rivers can strongly influence patterns of spatial and temporal distribution in benthic communities the structure and organization of the aquatic insect communities are greatly influenced by abiotic environmental conditions, biotic conditions, and dispersal processes (Wibowo and Santoso, 2017).

In Africa, particularly Nigeria, land use changes on different catchments area, agro-industrial activities and rapid urbanization pose threats to the well-being of aquatic environment and alters species composition and abundance of macroinvertebrates (Andem *et al.,* 2014). In the face of increasing human activity in catchments draining into the stream, there is a need to assess the current status of water quality and macroinvertebrates assemblage in Moussa stream and to test protocols for future monitoring.

STUDY AREA

Description of the Study area and Sampling stations

The study was carried out on Moussa stream in Bida Niger state. Bida is located in North Central Nigeria. The town lies within the latitude of 09^0 03' 8N and $09^0$06'40"N and longitude of $006^0$01'0"E and $006^0$02'42"E (Fig.1). The study sites lies in savannah region of North Central Nigeria. Bida is characterized by two distinct seasons (wet and dry season) the wet season is from April to October while the dry season is from November to March which is completely devoid of rain. ***Station 1*** is the reference point of the stream located at latitude 09°7.328'N, and longitude 006°0.709'E. The station is located along Bida-Zungeru road very close to Federal Government Girls College Bida. It has emergent macrophytes and it is surrounded by thick vegetation with palm trees making a canopy cover. This station is relatively free from human activities except farming due to its location in the outskirt of the town.

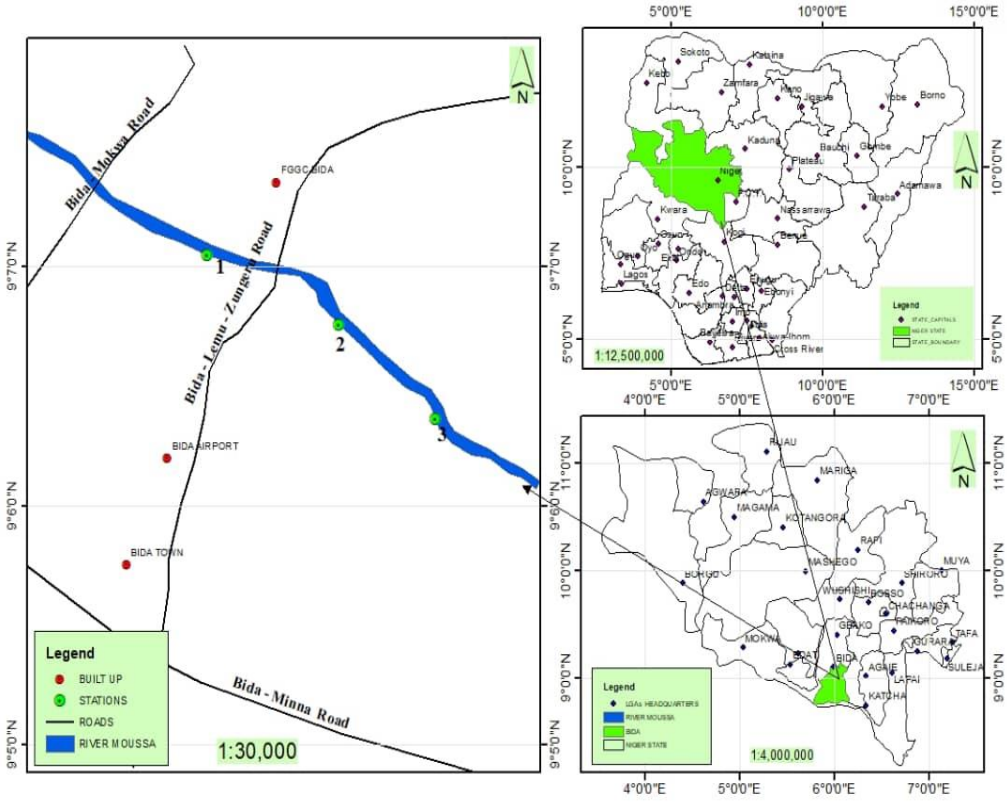

Fig. 1: Map showing sampling stations of Moussa stream Bida Niger state

Station 2 is located along Bida-Minna road very close to Talba Housing estate Bida, close to a motorable bridge on latitude of 09° 6.388'N, and longitude 006° 2.117'E. The station is characterized with few trees and vegetation with a large space thereby receiving thermal radiation directly from sunlight and is surrounded by farms. Human activities in this station are predominantly bathing, washing and farming. ***Station 3*** is located in the outskirt of Bida with a latitude of 09° 6.342'N and longitude, 006° 2.264'E. The station is characterized with few trees and vegetation surrounded by farms. Human activities in this station are predominantly farming throughout the seasons.

SAMPLING TECHNIQUES

Water sampling

Water samples for physicochemical parameters were collected monthly for a period of Eight (8) month (January to August, 2017) from three selected sampling station in Moussa stream. Sampling period covers both the dry and wet season. Temperatures, depth, flow velocity, dissolved oxygen (DO), Biochemical oxygen demand electrical conductivity, pH, alkalinity, turbidity, Nitrate and Phosphate where all determined using standard methods and procedures (APHA, 2012).

Macroinvertebrates sampling and analysis

Kick sampling technique (Hynes, 1961), was used to collect benthic macroinvertebrates monthly (January 2017 to August 2018) with the aid of a D-frame net (250µm mesh) within an approximately 25m wide portion of the streams. Samples were collected from all stations and were taken on different substrata (vegetation, sand, and gravel biotypes) and flow regime zones (riffles, runs, and pools). Samples collected were preserved in 70% ethanol and transported to the laboratory section of Department of Animal Biology, Federal University of Technology, Minna for identification. At the laboratory, macroinvertebrates were picked out with the aid of forceps and were observed using a stereoscopic microscope. Sorted Macroinvertebrates were identified to lowest taxonomic rank possibly to species level using the taxonomic keys according to Gerber and Gabriel (2002); Day *et al*., (2002); De Moor *et al*., (2003); Arimoro and James (2008) and Umar *et al.*, (2013).

Data Analysis

The physicochemical parameters data were analyzed by descriptive statistical test, using Microsoft Excel 2010. The mean, range and standard deviation of each physicochemical characteristic were calculated per station. Biological indices such as taxa richness and evenness (E) abundance, number of taxa, diversity index, dominance as well as physicochemical variables among all stations were compared using one way analysis of variance (ANOVA). Canonical correspondence analysis (CCA) was used to determine the relationship between macroinvertebrate communities and environmental variables using PAST statistical software.

RESULTS

Physicochemical parameters.

In Moussa stream, results showed that water temperature (24.9-27.5^{0}C), Depth (14.7-45.8cm), Flow velocity (0.14-0.23m/s), Biochemical oxygen demand (2.0-7.0mg/L), pH (6.33-8.6), Conductivity (20-63µ/cm), Alkalinity (8-30mg/L), Turbidity (61-285NTU), Nitrate (0.87-3.85mg/L) and Phosphate (0.31-1.01mg/L) were within the maximum permissible limit of WHO and SON except Dissolved oxygen (3.1-10mg/L). Most of the physico-chemical parameters investigated with the exception of depth and flow velocity showed no significant difference ($P>0.05$) among all the sampling stations, with Station3 recording a lower depth (22.58±2.29cm), similarly station3 (0.179±0.008m/s) was significantly higher than other stations as indicated by ANOVA. Temperature, depth and flow velocity showed no significant differences with season. However pH, DO, BOD_5, Turbidity Conductivity Alkalinity, Nitrate, and Phosphate were significantly higher during wet season as shown in table 1.

Macroinvertebrates assemblage

A total of 471 individuals from 30 species in 20 families of macroinvertebrates were recorded during the study period as shown in Table 2. Moussa stream Station 1, 2 and 3 recorded a total of 166(35.24%), 149(31.63%) and 156(33.12) as shown in table 2. Overall, there was significant difference ($P<0.05$) in number of individuals between the sampling stations during the sampling period.

Distribution of macroinvertebrates group

The abundance of taxonomic level revealed that Coleopterans, Odonata and Hemiptera were the most common groups encountered in the streams. Ephemeroptera was sparingly found in all stations except its abundance in station 1. Diptera, Mollusca, Oligochaeta and Decapoda were also found in good numbers as shown in figure 2.

TABLE 1

Physicochemical parameters measured at all the sampling station of Moussa stream in Bida, Niger state, Nigeria (January to August 2017).

Parameters	Station 1	Station 2	Station 3	Probability		Maximum permissible limit	
				Months	Stations	FEPA	SON
Temperature (ºC)	26.06±0.28 (25.2-27.1)	26.36±0.21 (25.1-27.2)	25.83±0.33 (24.9-27.5)	0.241	0.435		
Depth (cm)	29.4±2.24 (23.1-38.9)	34.31±3.09 (24.2-45.8)	22.58±2.29* (14.7-31.9)	0.255	0.014		
Flow velocity (m/s)	0.158±0.003 (0.15-0.18)	0.155±0.003 (0.14-0.17)	0.179±0.008* (0.15-0.23)	0.474	0.019		
pH	7.30±0.21 (6.33-8.1)	7.48±0.21 (6.33-8.3)	7.35±0.25 (6.33-8.6)	0.00027	0.837	6.0-9.0	6.5-8.5
DO (mg/l)	6.43±0.68 (3.1-8)	6.45±0.87 (3.1-10)	6.37±0.75 (3.1-10)	2.53E-07	0.997	5	
BOD_5 (mg/l)	4.0±0.45 (2.0-5.8)	4.2±0.57 (2.2-7.0)	3.88±0.42 (2.2-6.0)	0.0014	0.901	10	
Turbidity (NTU)	172±30.88 (61-285)	198±29.09 (71-285)	199±29.79 (70-265)	6.34E-09	0.761		
Conductivity (µS/cm)	42.25±4.39 (20-56)	47.12±4.75 (20-63)	43.75±6.27 (20-63)	4.17E-06	0.796		1000
Alkalinity (mg/l)	20±2.69 (8-30)	20.37±2.52 (10-30)	20.5±2.28 (10-30)	8.87E-09	0.989		
Nitrate (mg/l)	2.40±0.36 (0.87-3.83)	2.58±0.31 (1.31-3.66)	2.41±0.39 (1.01-3.85)	3.49E-06	0.936	20	50
Phosphate (mg/l)	0.63±0.08 (0.33-0.98)	0.67±0.09 (0.31-1.0)	0.68±0.09 (0.33-1.01)	7.90E-10	0.993	5	

Values are mean±S.E; range in parenthesis; values with asterisk (*) differs significantly. Federal Environmental Protection Agency (FEPA 1991). Nigerian Standard for Drinking Water Quality; Standard Organisation of Nigeria (SON, 2007).

TABLE 2

Distribution and Abundance of macroinvertebrates in Moussa stream Bida, Niger state, Nigeria from January to August 2017.

Order	Family	Species	Codes	Stations		
				1	**2**	**3**
Coleoptera	Dysticidae	*Phylodyte* sp.	Phyl	0	1	0
	Hydrophilidae	*Crenis sp*	Cren	5	22	10
		Hydrophilus sp.	Hydr	1	13	11
		Hyphydrus sp.	Hyph	0	2	2
		Culymbetes sp.	Culym	0	0	10
Ephemeroptera	Baetidae	*Buggilesia* sp.	Bugg	8	8	11
		Cloeon sp.	Chlo	72	6	6
Odonata	Coegnoridae	*Coenagrian* sp.	Coen	2	4	6
		Pseudogrian sp.	Pseu	4	7	4
	Plactinecmidae	*Mesocnemis* sp.	Meso	8	7	11
	Gomphidae	*Ophiogomphus* sp.	Ophi	0	2	5
	Aeshnidae	*Aeshna* sp.	Aesh	1	9	12
	Cordullidae	*Epitheca* sp.	Epit	0	4	2
		Cordullex sp.	Cord	2	0	0
	Libellubidae	*Libellula* sp.	Libb	7	0	0
		Zyxomma sp.	Zyxo	5	0	3
		Brachythermis sp.	Brac	8	4	1
Hemiptera	Nepidae	*Ranatra* sp.	Rana	6	1	3
		Laccocotrephes sp.	Lacc	11	17	13
	Hydrometridae	*Hydrometra* sp.	Hydrom	2	1	0
	Naucoridae	*Macrocroris* sp.	Macro	0	5	9
		Naucoris sp.	Nauc	0	2	2
	Notonectidae	*Notonecta* sp.	Noto	4	4	3
	Gerridae	*Gerris* sp.	Gerr	3	2	1
Diptera	Chironomidae	*Chironomus* sp.	Chir	5	7	15
Mollusca	Unionidae	*Unio mancus*	Unio	0	3	6
	Physidae	*Physa* sp.	Phys	1	2	0
Oligochaeta	Hirudinidae	*Hirudina* sp.	Hiru	0	0	1
	Lumbriculidae	*Lumbricoides* sp.	Lumb	0	16	9
Decapoda		*Caridina gabonensis*	Cari	11	0	0
				166	**149**	**156**

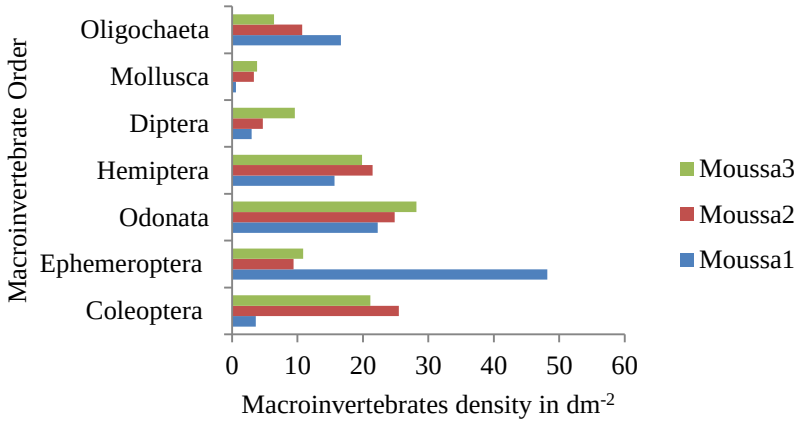

Fig. 2: Total distribution and abundance of recovered groups of macroinvertebrates in the sampling stations of Moussa stream, Bida, Niger state January to August 2017.

Seasonal changes in population of macroinvertebrates

The percentage and number of individuals of macroinvertebrates recorded during the study period of the stream shows that 67.09% (316 individuals) were recorded in dry season (January to April 2017) and 32.91% (155 individuals) were recorded in wet season (May to August 2017). Higher abundance was recorded in dry season than wet season in all the sampling stations as shown in figure 3.

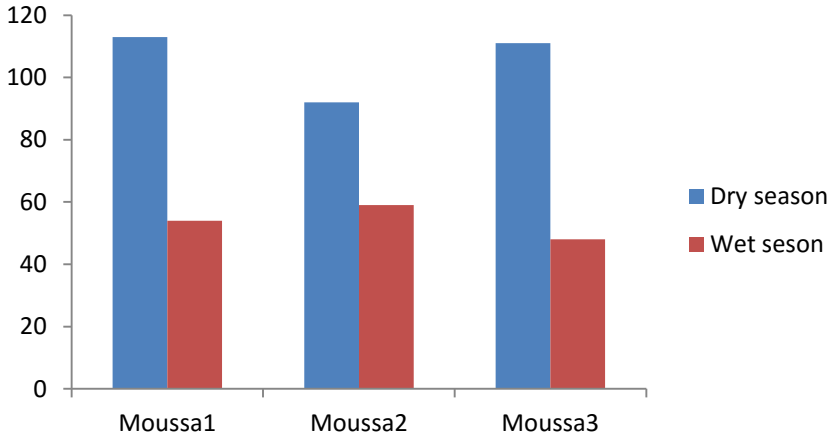

Fig. 3: Seasonal assemblage of macroinvertebrate in sampling stations of Moussa stream Bida Niger state

Diversity, Moussa Stream Bida Niger State

Biological indices including abundance number of taxa Shannon-Wiener diversity, evenness and Margalef's indices calculated for each stations of the stream are shown in Table 3. The highest number of species (25) was recorded in Station 2 and Station 3, while 21 species was recorded in Station 1. Number of individuals was highest in Station 1 (166), followed by Station 3 (156) and Station 2 (149). Station 3 recorded highest Simpson, Shannon and Evenness index followed by Station 2 and Station 3 while the lowest was recorded in Station 1. Station 2 recorded the highest in Margalef's index (4.7823) followed by station 3(4.735) and station 1 (3.908) recording the lowest.

TABLE 3

Diversity indices of the recovered benthic macroinvertebrates of Chikke and Moussa stream in Bida, Niger state

Diversity indices	Station 1	Station 2	Station 3
Species	21	25	25
Individuals	166	149	156
Simpson index	0.7908	0.9276	0.9421
Shannon index	2.258	2.873	2.983
Eveness index	0.4554	0.7078	0.7897
Margalef index	3.908	4.783	4.735
Dominance_D	0.2092	0.07241	0.05787

Relationship between Macroinvertebrate and measured physicochemical parameters

The canonical correspondence analysis (CCA) ordination positively correlated between species abundances and measured environmental parameters (Fig. 4). The total variation in macroinvertebrates assemblage composition in the studied stations of the stream was equivalent to 1.50 eigenvalues, where 0.58, 0.54 and 0.39 were for axis 1, 2, and 3, respectively. However, the first CCA axis accounted for 19.98% of the variation in the data set, the second axis account for 18.8 % of the variation in the data set and the third axis accounted for 13.39% of the data set which result in total variance of 56.5%. Organisms in axis 1 were mostly affected by Nitrate, Conductivity, Dissolved oxygen, Biochemical Oxygen Demand and flow velocity. CCA axis 2 accounted for 18.8% of variation in data set, organism in axis 2 were affected by Phosphate, Temperature pH and Alkalinity.

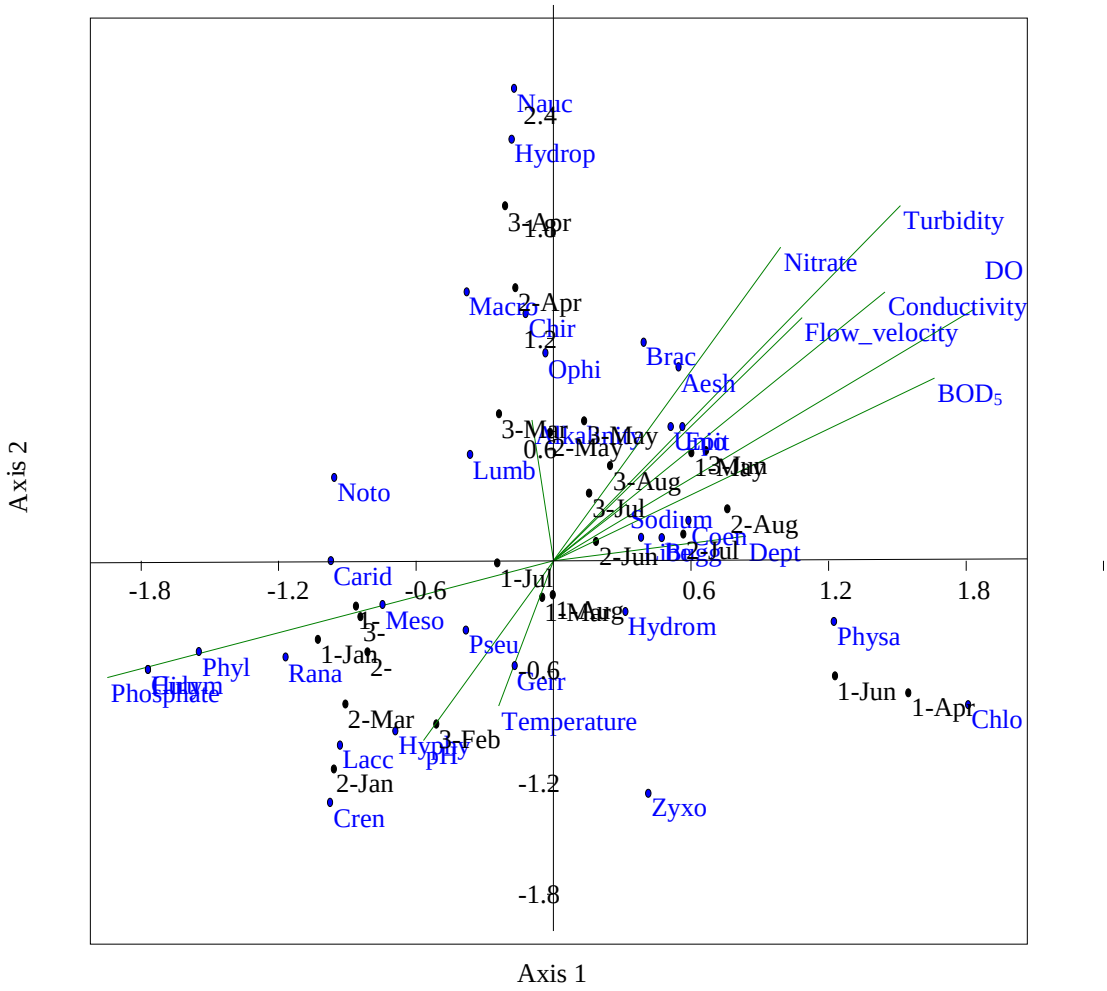

Fig. 4: Canonical correspondence analysis (CCA), Tri-plot of first and second CCA axis of macroinvertebrates and environmental variables of Moussa stream.

DISCUSSION

Physicochemical parameters of Moussa stream

In most parts of Africa and other developing countries, people live in the riparian zones of streams and rivers for supply of water for their daily needs, resulting in the pollution of these water bodies (Arimoro *et al.*, 2015). The physical, chemical

and biotic characteristic of most aquatic ecosystems in Nigeria have been compromised because of discharges of organic and inorganic waste from activities on the catchments of most freshwater bodies (Arimoro and Ikomi 2008; Andem *et al.*, 2014). The medium temperature range (24.6 to 27.8^{0}C) from this study could be as a result of the time of sample collection and the vegetation cover around the stream. Temperature is one of the important environmental variables because it regulates the physiological behavior and distribution of aquatic organism (Mustapha, 2008). There is a sharp increase in depth and flow rate during the wet seasons, this could be as a result of increase in the water volume as a result of rain and which were absent during dry season. The pH value observed exceeded the recommended range of 6.5 to 8.5 (SON, 2007). This could be as a result of surface run off or decay of organic matters in the water (Mustapha, 2008). Higher Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD_5) and Turbidity observed in this study is an indication of well oxygenated water body throughout the study period which involved both dry and wet season. Higher DO, BOD_5 and turbidity were recorded in wet season than in dry season, this could be as a result of increase in volume of water in wet season, influx of organic matters into the stream through surface run off, erosion and high temperature coupled with high sunlight intensity in the dry season (Raji *et al.*, 2015). High value of Conductivity and Alkalinity observed in the dry season than in wet season indicating that the sampling station might contain more amount of suspended and dissolved solid materials, which increases the concentration of cation such as calcium and magnesium (Mustapha, 2008). High content of Nutrient such as nitrate and phosphate could be as a result of surface run off from farms, decomposition of organic matters into the water and different anthropogenic activities around the water body (Arimoro *et al*., 2015).

Macroinvertebrate Groups Assemblage and Distribution.

A total of 471 individuals with 30 macroinvertebrate species were recorded in Moussa stream during the study period. This number is low compared to other studies from north central Nigeria (Dadi-Mamud *et al*., 2014; Arimoro and Keke, 2016). The low abundance of individuals and diversity of Macroinvertebrate in this study could be attributed to the nature of the habitat, which includes the presence of vegetation cover and the substrate type. Nature of vegetation canopy cover, sandy substrate could be attributed for favoring diverse groups of macroinvertebrates (Arimoro *et al*., 2015). Surface run off or Organic materials washed into the river also favored the distribution of certain groups. High abundance of coleopterans were found in all the sampling stations of the stream particularly areas which are moderately polluted. Coleopterans are associated with organically polluted water bodies because of the nature of their exoskeleton and their ability to renew oxygen supply directly from the environment and thus remain unaffected by oxygen depleting waste (Emere and Nasiru, 2008). The presence and abundance of Odonatans, coleopterans and Hemiptera in all the

sampling stations from this study indicate that they are moderately intolerant to pollution. Most families in this group were found as a result of the vegetation cover or the bottom sediment of the streams favoring their colonization. Similar findings have also been reported in other Nigeria water bodies (Arimoro and Ikomi, 2008; Emere and Nasiru, 2008; Edegbene *at al.,* 2015; Arimoro and Keke 2016).

Ephemeroptera were sparsely represented by two species which are *Bugillesia* sp and *Cloeon* sp. This is as a result of their sensitivity to polluted environment and the deteriorated state of both streams by the riparian users. Using the EPT index, Plecoptera and Tricoptera were absent throughout the study period. The low abundance of Ephemeroptera and Absence of Plecoptera and Trichoptera in sampling stations of both streams is an indication of gross pollution due to anthropogenic activities at the stations, since many studies have reported higher abundance and diversity of this group of macroinvertebrate to clean and pollution free water bodies (Arimoro and Ikomi, 2008; Arimoro and Keke, 2016).

The presence of other pollution tolerant groups such as Dipterans, Mollusca and Oligochates are indication of pollution caused by decaying organic waste in water body (Edegbene *et. al*., 2015; Arimoro and Keke 2016). These groups are majorly found in polluted environment and they are tolerant of pollution (Arimoro and Ikomi, 2008). In terms of seasonal assemblage high abundance of macroinvertebrate were encountered during the dry season than in the rainy season. This could be as a result of the increase in volume of water during wet season, increase flow characteristics and surface run off from surroundings environment which must have destabilized habitat structure during wet season. Similarly higher abundance of macroinvertebrates were recorded in the dry season in many streams of Nigeria (Arimoro and Ikomi, 2008; Keke *et. al.,* 2017). There is a positive correlation between the measured environmental variable and macroinvertebrates species presence in both streams. For over a period of time, there has been increasing activities around our water bodies which is due to increase in urbanization and industrialization. Increase in Human activities around the stream, eroded stream banks and Agricultural activities around the stream also have impact on water quality and distribution of aquatic organisms.

CONCLUSION

The low relative abundance of pollution sensitive organisms, especially the EPTs (Ephemeroptera-Plecoptera-Tricoptera) indicates clearly that Moussa stream is stressed across its reaches. However, water quality was perturbed more during the rainy season, possibly because of the unstable nature of the substrates, eroded stream banks and agricultural activities around the stream during the rainy season months, as observed by the increase in diversity and abundance during the dry season.

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