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RESEARCH ARTICLE

COMMUNITY PATTERN AND DIVERSITY INDEX OF MACRO-INVERTEBRATES IN RELATION TO SURFACE WATER INTERFACE OF RIVER NDAKOTSU, LAPAI NIGERIA

***[1]Dadi-Mamud, N. J., [2]Oniye, S. J., [2]Auta, J. and [3]Ajibola, V. O.**

[1]Biology Department, IBB University Lapai, Nigeria
[2]Department, of Biological Sciences, ABU Zaria, Nigeria
[3]Chemistry Department, ABU Zaria, Nigeria

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ABSTRACT

Community pattern and diversity index of macro-invertebrates in relation to Surface water interface of River Ndakotsu (latitude 9^0.34N and longitude 6^0.30E), Lapai, Nigeria was conducted from November 2010 to October 2012, using the modified kick sampling technique. Five stations were selected from upstream to downstream base on anthropogenic activities and ecological status of the River. Water quality changes indicated significant differences ($p<0.05$) in water and air temperatures, depth, turbidity, velocity, conductivity, pH, water hardness, total alkalinity; nitrate-Nitrogen and phosphate-phosphorus, but insignificant ($p>0.05$) in BOD_5 and COD between the five sampled stations within the months. Higher values of these parameters were observed at the impacted station 3. The total number of taxa and individuals analyzed at stations 1, 2, 3, 4 and 5 were 8(788), 5(488), 4(120), 8(1366) and 11(1699) respectively. Comparisons of abundance values demonstrated high significance ($p < 0.05$) between the impacted station and the upstream (station 1) and downstream station (station 5). Station 5 had the highest species richness, evenness, and diversity; while the anthropogenic activities in station 3 altered the water chemistry as well the richness, evenness and diversity of the species. The significant role of dissolved oxygen in the abundance and diversity of macroinvertebrate is well correlated in the study, where high abundance and species divers were recorded in stations with the highest dissolved oxygen levels. The presence of *Musca sobens* and Culex pipiens present in station 3 (impacted station) and 2 (partially impacted) is a characteristic of polluted waters. While *Biomphalaria grabrata, Lymnaea natalensis and Bullinus globosus* are vectors of parasites that causes diseases.

INTRODUCTION

Water is one of the most precious resources, but as the human population grows the demands on water supply increase. In addition to the increasing demand on water, humans impact ecosystems directly through land use change and indirectly by generating non-point source pollution that is introduced into streams and rivers via urban runoff. The need for clean water environment has aroused great interest and concern by many nations of the world. Contamination of streams, lakes, underground water, bays, or oceans by substances is harmful to living things. Studies have shown that biota differ greatly with changes in physico-chemical conditions in aquatic ecosystems (Saad *et al.,* 1990). The worldwide deterioration of surface water quality has become a growing threat to human society and natural ecosystems (Adeogun *et al.,* 2011). The physical environment of Rivers places many constraints on organisms as well as on type and form of food that is available.

****Corresponding author: Dadi-Mamud, N. J.,***
Biology Department, IBB University Lapai, Nigeria

Many water- dwelling organisms exploit the physical characteristics of river to obtain their foods. Generally, rivers are characterised by many interacting physical factors that produce spatial and temporal heterogeneity which may exert a major influence on benthic communities (Arimoro *et al*, 2007). Macro-invertebrates are organisms that inhabit the bottom substrate, in aquatic habitat for at least part of their lifecycle (Ajao and Fagade 2002). They are important as food for fish shellfish species in most aquatic environment where they are the secondary producers. They also play a central role in the flow of materials and energy through most terrestrial and benthic fresh water food –webs (Holloway and Barrow, 1983). Macro-invertebrates as well as other components of the aquatic biota have been used extensively to evaluate the degree of anthropogenic disturbance to biotic lotic and lentic ecosystems. Work on aquatic organisms in the tropics has shown that the quantitative collection of key groups in areas of natural vegetation or that modified by man can provide a means of estimating various ecological parameters, such as richness or evenness in diversity (Holloway and Barrow, 1983). Mbah, 1987 stated that information gathered from the study of aquatic insects will be very useful to limnologists and fishery scientist, as well as those involved in monitoring the impact of pollution on continental aquatic ecosystems. Assessing the ecological status of rivers, creeks and streams is a fundamental and increasingly important water management issue worldwide. In order to manage any aquatic habitat effectively it is important that basic information should be obtained on the fauna under relatively undisturbed conditions. Macro-invertebrates make good study specimens because they are abundant, readily surveyed and taxonomically diverse (Kerst and Anderson, 1975).

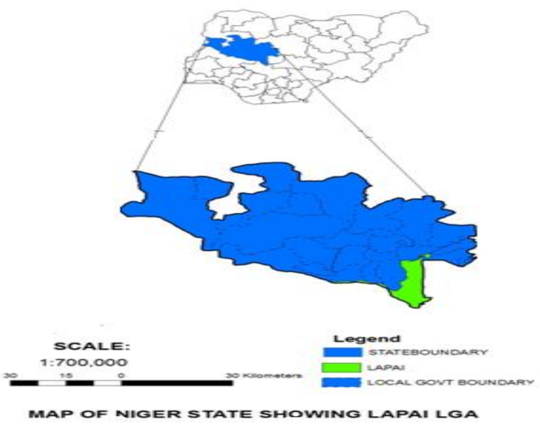
MATERIALS AND METHODS

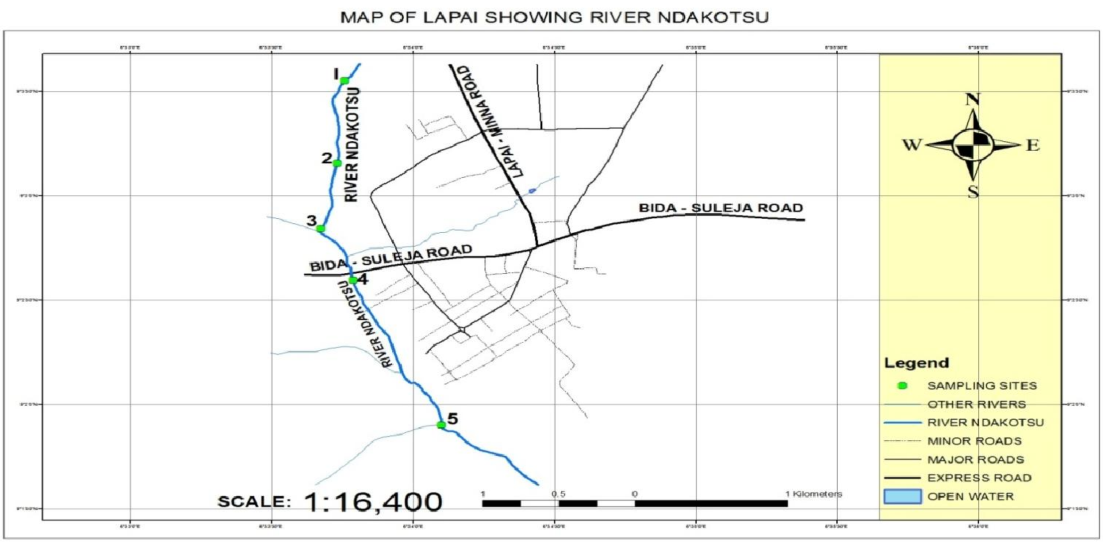
Description of the study area

River Ndakotsu located in Lapai Local Government area has the characteristic tropical climate of two distinct seasons; a dry season (November–April) and a wet season (May–October). The mean annual temperature is approx. 28 °C (range 22–34 °C) with mean annual relative humidity 85%. The river is fed principally by precipitation, municipal effluent and surface run off from the riparian communities. It flows through the outskirt main town of Lapai from Makkara and then join with river Dangana forming a confluence which empties into River Baro and finally empties into River Niger. It serves as source of drinking water, domestic needs, artisanal fishing as well as dumping site of effluents. The municipal runoffs as well the runoffs of the fertilizer and herbicide residue used for agricultural purposes are also discharge into the river

Sampling stations

Five locations were chosen based on the different ecological factors, anthropogenic activities taking place around the river and confluence created by other tributaries. Station 1 is located about 50m upstream from the source of the river and about 3km from each of the stations and with each others, with vegetation consists mainly of *Elaeis guineensis* and *Cocos nucifera* L. Human activities here include subsistence farming, washing and bathing. Station 2 is located behind the Lapai general hospital and human activities here include fishing, dumping of refuse, bathing and washing of clothes and vehicle. The dominant macrophytes in this sampling station are *Pandanus sp*, *Ceratophyllum submersum* L, *Nymphaea sp* and *Mitragyna ciliate.* Station 3 is a tributary located off stream, where domestic waste and seawage are the major sources of pollutants being discharge and then emptied to the river, it is flanked by *Bambusa* sp. and Elaies. guineensis. Abundant emergent macrophytes are *Pandanus* sp and *Mitragyna ciliate.* Station 4 is located at the discharge point of a reservoir by the Water Board with various activities like bathing, washing of clothes and vehicles, farming activities, and fishing it is characterized by tree canopy like *Pistia stratiotes* (Linn.) *Salvinia nymphellula* Desv, *Nymphaea lotus* (Linn) and *Vossia cuspidats* (Roub). Station 5 is located downstream, just below Lapai abbatoir. The abattoir effluent is composed of faecal matters, blood and ashes from burning and roasting of animals. It is being joined by river Dangana forming a confluence.





Farming and fishing activities, washing and bathing also takes place at this station. Major plant species in this sampling station are *Nymphaea sp*, Utricularia sp. and Salvinia sp.

Water quality analysis

Field determinations

Air and water temperature, pH, Conductivity and Total dissolved solids were measured in-situ using a HANNA portable combo waterproof pH/EC/TDS/Temperature, Tester model HI 98130.Transparency was evaluated using Secchi disc as described by Boyd (1981). Water velocity was determined using the Pin-pong floatation technique and Water Depth was measured with the use of a rope and a metre rule. Dissolved Oxygen (DO) was determined using Digital D.O meter model 6 11-R Labtech.

Laboratory analysis

Water samples were collected in sample bottles, labeled appropriately, stored in a portable cool box ande transported to Ibrahim Badamasi Babangida University laboratory for analysis. BOD was determined by modified Winkler Azide method (APHA, 2005), while COD and Alkalinity were determined as described by ASTM (2001). Nitrate- Nitrogen and Phosphate-Phosphorus were determined using HACH DR /2010.

Macro invertebrate sampling and analysis

Kick samples of macro invertebrates were collected monthly from November 2010 to October 2012, using a 50–100 mm D-frame net of 500 µm mesh. Four samples were taken at each sampling site per sampling occasion to include all available substrata (vegetation, sand and gravel biotopes) and flow regime zones (riffles, runs and pools). The four samples were pooled to create a single sample for each site and preserved in 70% ethanol. In the laboratory, samples were washed in a 500 µm mesh sieve to remove sand, and the macro invertebrates were picked from the substrata, they were then identified using keys (Barber-James and Lugo-Oritz 2003) and (Merritt and Cummins 1996).

Statistical analyses

For community structure analysis, Shannon-Wiener diversity index, dominance and species evenness were determined using PAST for windows (2007) statistical software. Individual and combined MANOVA was used to determine the level of significance among the parameters measured, and if significant, Tukey's honest significance difference test was employed to separate the means. Canonical Correspondence Analysis was used to determine relationship between the different parameters

RESULTS

Table 1 summarizes the mean values of the various parameters monitored at the five (5) selected stations as revealed by multivariate analysis of variance (MANOVA). Turkey's honest significant difference test (HSD) shows the significant difference between the parameters at all stations throughout the months within the four seasons. The spatio-temporal air temperature of the study area varied between 26.03^{0}C ±0.60 to 27.01^{0}C ±0.49, while that of water temperature was 25.73 ^{0}C ±0.45 to 26.63 ^{0}C ±0.42 (table 1). Multivariate analysis of variance (MANOVA), shows significant variation at (P<0.05) for the stations, months and seasonal means (table 1). Also there was significant difference between the water temperatures at all stations and months, with station 3 the source of variation according to (HSD). Table 1 shows the monthly water depth range variation from 7.24±0.2cm to 40.39±1.75cm. MANOVA shows that there were significant differences in the months, stations and seasons. Honest significant difference tests, revealed that station 1 had no significant difference with station 2, but had significant differences with stations 3, 4 and 5 (table 1). The monthly mean water velocity varied between 0.18±0.07 cm/s to 0.39±0.04 cm/s, while two ways analysis of variance (table 1), showed that there were significant differences (P<0.05) during both wet and dry seasons. The mean separation showed significant differences between mean water velocity at station 5. The turbidity of the river mean value ranged from 20.14±2.78 NTU 72.49±13.90 NTU, there was significant differences (P< 0.05) between the station but insignificant (P≥0.05) within the months (table 1).

The pH of the water varied between 6.4 and 7.0, the difference in pH values in the various stations as well as between the wet and dry season months did test statistically different (P<0.05). Station 3 had the highest value (317.00mg/l) of total alkalinity in the wet season, while station 2 had the lowest (8.00mg/l) in the month of Jan, the dry season (table 1). The dissolved oxygen (DO) concentration fluctuated between monthly mean of 3.54 ±0.22 mg/l to 6.14±0.17 mg/l, Dissolved oxygen had no significant differences within the months, but have significant difference among the stations. Stations 1 and 3 are the sources of the differences observed in these parameters as revealed by turkey's honest significant differences test (table 1). Biological oxygen demands (BOD_5) concentration values varied from 10.57±1.94 mg/l to 14.55±1.46 mg/l. There was no significant differences (P>0.05) between the mean water BOD_5 at all the stations and within the months (table 1)

Chemical oxygen demand (COD) concentrations ranged between 20.25±3.60 mg/l and 28.69±2.81 mg/l. Multivariate analysis of variance (MANOVA), revealed that there were significant differences observed among the stations and within the months during both wet and dry seasons (table 1). Total alkalinity had significant differences among all the stations sampled within the months during the both seasons as revealed by MANOVA (table 1). Stations 1 and 2 had no significant difference, while significant differences were obtained for stations 3, 4 and 5. The hardness of the river varies within the month and among the stations, with station 3 being different from stations 1 and 2 which are not significantly different as well stations 4 and 5 which are also not significantly different as revealed by HSD (table 1). Nitrate-Nitrogen (NO_3 - N) concentrations shows significant variations among the stations and months, and within the seasons with stations 1 and 3 being the source of the significant variations as revealed by turkey's honest significant difference tests. Table 1 shows that there were insignificant difference (P>0.05), but significant (p<0.05) as observed with the months in Phosphate-phosphorus concentrations.

Table 1. Multivariate analysis of variance for spatial and temporal variations of physicochemical parameters of the study stations, River Ndakotsu from Nov. 2010 to Oct. 2012

S/N	Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	F-value ANOVA	
							Months	Stations
1.	Air temperature (^{0}C)	26.03±0.60^{a} (22.00-33.00)	26.51±0.49^{ab} (21.00-32.00)	26.92±0.60^{ab} (22.00-33.00)	27.01±0.49^{b} (21.00-31.20)	26.65±0.40^{ab} (20.50-31.00)	21.40*	2.95*
2.	Water temperature (^{0}C)	25.98±0.35^{ac} (23.00-31.00)	26.20±0.43^{ac} (20.00-30.00)	26.63±0.42^{a} (21.00-31.00)	25.90±0.44^{bc} (20.00-30.00)	25.73±0.45^{bc} (20.00-29.00)	24.12*	3.79*
3.	Water depth (m)	13.25±0.67^{a} (18.00-20.00)	15.96±0.61^{a} (11.00-22.10)	7.24±0.26^{b} (4.50-10.30)	40.39±1.75^{c} (25.50-63.00)	21.10±1.37^{d} (9.50-35.60)	4.53*	234.0*
4.	velocity (m/s)	0.18±0.07^{a} (0.14-0.29)	0.19±0.0^{a} (0.08-0.33)	0.31±0.03^{bc} (0.09-0.67)	0.39±0.04^{c} (0.12-0.67)	0.27±0.02^{d} (0.13-0.59)	2.70*	18.93*
5.	Turbidity (NTU)	37.81±6.56^{a} (4.00-97.00)	20.14±2.78^{a} (6.00-57.00)	72.49±13.90^{b} (7.00-239.86)	42.20±5.10^{a} (7.00-90.00)	37.25±5.02^{a} (8.00-78.05)	1.29	6.48*
6.	pH	6.4(5.2-8.6)	6.5(5.8-8.3)	7.0(5.9-8.8)	6.7(6.0-8.7)	6.7(6.0-8.6)	12.23*	10.67*
7.	Total alkalinity (mg/l$CaCO_3$)	38.65±3.72^{a} (10.0-66.00)	39.92±3.11^{a} (8.0-60.0)	188.25±17.94^{b} (12.40-317.0)	94.05±12.85^{c} (120.0-210.0)	109.80±12.37^{cd} (22.25-230.0)	5.57*	54.51*
8.	Water Hardness (mg/L)	39.75±4.31^{a} (10.0-87.00)	52.92±5.51^{a} (17.0-118.0)	183.96±17.34^{c} (24.00-315.00)	102.25±14.7^{d} (8.00-247.00)	112.55±14.30^{d} (26.0-260.00)	5.16*	38.8*
9.	Dissolved oxygen (mg/l)	6.14±0.17^{a} (3.9-6.9)	5.32±0.51^{ab} (3.91-6.41)	3.54±0.22^{c} (2.00-5.68)	5.08±0.34^{b} (2.05-7.20)	5.15±0.20^{b} (3.6-6.9)	2.27	22.04*
10.	Biochemical oxygen demand (mg/l)	10.57±1.94^{a} (1.85-31.35)	12.48±2.04^{a} (1.1-28.6)	14.55±1.46^{b} (1.12-25.60)	11.39±1.04^{a} (3.5-28.00)	12.47±1.46^{a} (4.5-28.0)	1.39	0.90
11.	Chemical oxygen demand (mg/l)	20.25±3.60^{a} (3.5-57.00)	23.26±3.83^{a} (2.0-52.0)	28.69±2.81^{c} (2.00-48.00)	21.65±1.50^{ab} (10.0-42.00)	25.21±2.44^{b} (8.00-45.00)	0.94	1.23
12.	NO_3-N (mg/L)	0.87±0.07^{a} (0.39-1.70)	1.85±0.20^{b} (0.35-35.0)	3.01±0.19^{c} (0.62-0.45)	2.23±0.25^{d} (0.01-4.00)	1.70±0.29^{b} (0.02-4.8)	3.47*	19.65*
13.	PO_4-P (mg/L)	0.71±0.13^{a} (0.12-2.75)	0.77±0.11^{ad} (0.18-2.34)	2.26±0.34^{b} (0.1-5.12)	1.35±0.28^{c} (0.18-6.7)	0.85±0.10^{d} (0.19-2.31)	1.76	10.28*

***Note**: values are mean ± S.E. (minimum and maximum values are in parentheses). Different superscript letters in a row show significant differences (P < 0.05) indicated by Tukey Honest significant difference tests. * indicates significantly calculated F-value.*

Table 2. Composition, relative abundance and distribution of Macro-invertebrates in five stations in River Ndakostu, Lapai -Niger State from November, 2010 to October, 2012

Organisms			Sampling Stations						
Order	Family	Genus/Species	1	2	3	4	5	Total	%
Arachnida	Melaniidae	*Melanoides moerchi*	-	-	-	-	200	200	4.48
	Planorbidae	*Biomphalaria grabrata*	22	-	26	26	-	74	1.66
Gastropoda	Lymnaeidae	*Lymnaea natalensis.*	57	-	-	-	148	205	4.6
	Bulinidae	*Bullinus globosus*	44	-	-	26	148	456	10.22
Coleoptera	Gyriinidae	*Orectogyrus* sp.	162	-	-	-	98	260	5.83
	Hydrophilidae	*Amphios sp.*	-	-	-	91	-	91	2.04
		Helochares sp.	-	104	-	105	-	209	4.69
Diptera	Chironomidae	*Chironomus* sp.	327	-	-	-	-	327	7.33
	Tipulidae	Cranefly larvae	-	57	-	-	-	57	1.28
	Muscidae	*Musca sobens*	-	-	25	-	-	25	0.56
	Cullicidae	*Culex pipiens*	-	25	19	-	-	44	0.99
Hemiptera	Gerridae	Neboandelus africana	76	-	-	67	277	1023	22.93
		Gerris lacustris	53	27	-	40	231	351	7.87
	Vellidae	Veelia sp	-	-	-	-	195	195	4.37
		Mesovelia sp.	-	-	-	73	149	222	4.98
	Corixidae	Micronecta sp.	-	-	-	-	82	82	1.84
	Pleidae	Plea sp	-	-	-	-	59	59	1.32
	Belostomalidae	Appasus sp.	-	-	-	-	112	112	2.51
	Naucoridae	Naucoris sp.	47	275	50	97	-	469	10.51
	Total		788	488	120	1366	1699	4461	100.00

Table 3. Diversity of macro-invertebrates of River Ndakotsu from Nov.2010 to Oct.2012

	station_1	station_2	station_3	station_4	station_5
Taxa_S	8	5	4	8	11
Individuals	788	488	120	1366	1699
Dominance_D	0.241	0.3823	0.289	0.2974	0.1062
Simpson_1-D	0.759	0.6177	0.711	0.7026	0.8938
Shannon_H	1.716	1.216	1.315	1.568	2.313
Evenness_e^H/S	0.6956	0.6746	0.931	0.5996	0.9184
Margalef	1.05	0.6462	0.6266	0.9696	1.344

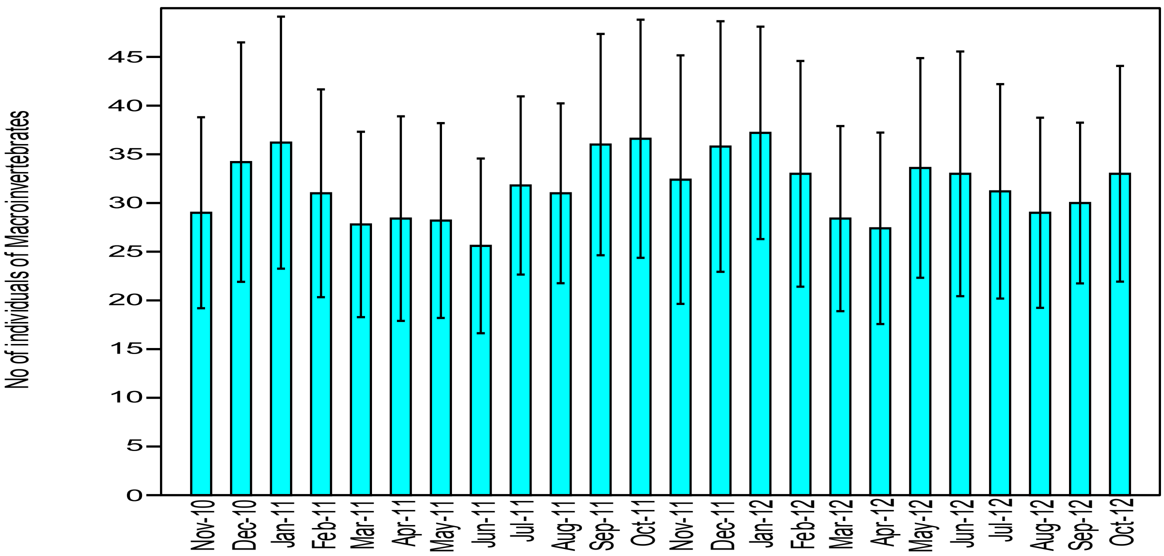


Fig. 1. Monthly variation of macro invertebrates in the study stations of River Ndakotsu from Nov 2010 – Oct 2012

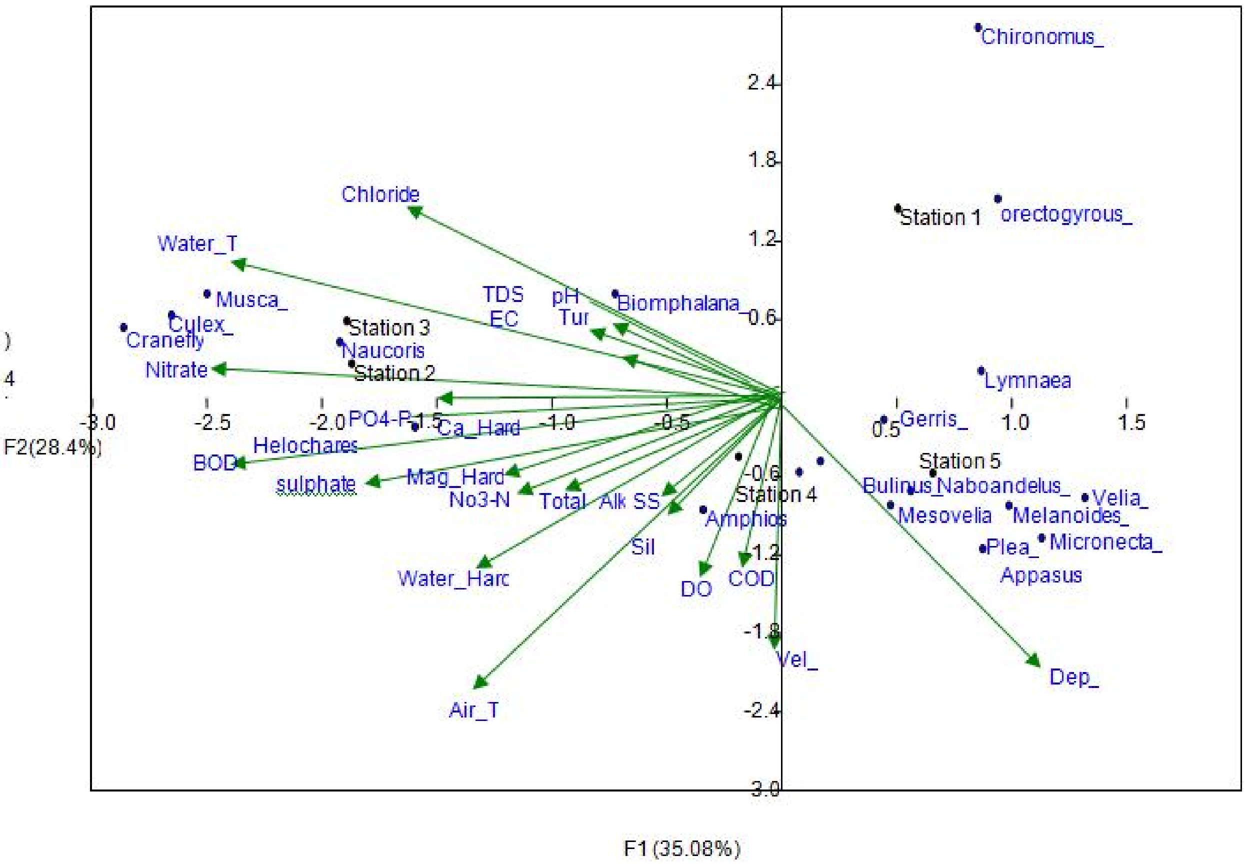


Fig. 2. Canonical Corrspondence Analysis for the physicochemical parameters and macrobeninvertebrates analysed in the five stations of River Ndakotsu

Mac invertebrates

The taxonomic composition, density and distribution of macro invertebrates in the study area are shown in table 2.The assemblage fall into five orders, sixteen families, nineteen taxa comprising four thousand four hundred and sixty one (4,461) individuals were recorded during the entire study period. The total number of taxa and individuals analyzed at stations 1, 2, 3, 4 and 5 were 8(788), 5(488), 4(120), 8(1366) and 11(1699) respectively (table 2). The temporal distribution in abundance of macro invertebrates in the study area throughout the sampling period is shown in Figure 2, with the highest distribution in January, 2011 dry season while the highest in the month of June, 2011 wet season. Table 3 shows the diversity summary and dominance indices calculated for the five sampling stations. The richness calculated by Margalef index (d) was highest in station 5 (1.344), followed by station 1 (1.05) and station 3 accounted for the least (0.6266). Shannon diversity (H) and maximum possible diversity were higher in station 5 (which was statistically significant ($P<0.05$), followed by stations 1, 4, 3 and 2 in that order. For evenness, station 3 was more even (0.931), followed by station 5 (0.9184) and station 4 had the least evenness value (0.5996), while Berger-Parker's dominance index was highest in station 2 and lowest in station 5. Canonical correspondence analysis showed that, *Neboandelus Africana, Bullinus globosus, Mesovelia sp, Velia sp, melonoides moerchi, Plea sp, Micronecta sp* and *Appasus sp* were positively associated with depth, and velocity, but sensitive to chloride, total dissolved solids, EC, pH, turbidity, water temperature and nitrates in station 5. *Helachores sp* and *Amphios sp* had negative correlation with BOD, NO_3-N, PO_4-P, magnesium and calcium hardness, SS, sulphate, total alkalinity, water hardness silica, DO and COD, water hardness and air temperature and related to velocity in station 4, while *Musca sobens*, *Culex pipiens*, Cranefly larvae, *Biomphala grabrata,* and *Naucoris sp* in stations 3 and 2 had positive correlation with chloride, water temperature, nitrate, TDS, EC, pH and Turbidity. The variations in the first two axes (cumulative eigen percentage) amounted to the 63.48% of the total variation (Fig 3)

DISCUSSION

The total number of diptera reported in the study is low, similar with earlier studies by Ogbeibu and victor (1989), Edokpayi *et al*. (2000) and Adakole and Annune (2003), which reported 19, 13, and 18, respectively in Nigeria fresh water systems and contrary to the study by Arimoro *et al*. (2007), which reported 24 taxa. The recorded high abundance of individual diptera at station 3 as compared to the upstream and down streams station, probably could be as a result of the opportunistic species monopolizing the available resources or further exhibiting certain adaptations to survived these condition (Mason, 1991; Arimoro *et al*., 2007) Again it is possible that the organic pollutant has been directly or indirectly used as food source, and completion and predation for the remaining species. Similar studies elsewhere by the following authors (Solimini *et al*., 2000; Brown, 1996; Ravera, 2001; Rueda *et al*., 2002) revealed that dipters abundances could be due to considerable load of organic particles from untreated sewage and live stock effluences. The presence of *Musca sobens* and *Culex pipien*s in station 3 and 2 is a characteristic of polluted waters. Their presences have been reported in grossly polluted shallow waters and they are known to exist in waters in high density that is depleted of oxygen (Hellawell, 1986). Their dominance is also presumably favored by the rich supply of particulate organic matter. The most represented family Hemiptera could be attributed to the environmental condition of the river which favors their reproduction and growth *Biomphalaria* sp and *Bullinus globosus* are snails that serve as host for the blood Fluke (Schistosome) that causes Schistosomiasis**.** The Centers for Disease Control and Prevention estimates that 150 to 200 million persons throughout the world are afflicted with schistosomiasis (CDC, 2009). *Lymnaea* stagnalis is an intermediate host for *Moliniella anceps* the parasite of meadow birds (Rallidae (Kudlai, 2009). The recorded higher macro- invertebrates in a station than other stations may be as a result of high level of particulate organic matter and presence of macro nutrients which favors the growth of phytoplanktons.. The significant role of dissolved oxygen in the abundance and diversity of macro invertebrate is well correlated in the study, where high abundance and species divers was recorded in stations with the highest dissolved oxygen levels

Conclusion

Nigeria contains ocean, lagoon, rivers, swamps and wetlands which are valued globally for their biodiversity. The absence of Ephemeroptera indicates that the environmental conditions here are already stressed, along the whole river. This study provides information on the present status of the water quality and a baseline survey of macroinvertebrates in a representative river, forming the foundation for long-term assessment and for the use of bioindicators for environmental monitoring and management of this system.

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