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MULTIVARIATE APPROACH TO THE STUDY OF AQUATIC SPECIES DIVERSITY OF DENDRITE STREAMS OF RIVER KANO, NIGERIA

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ABSTRACT
Diversity of macroinvertebrates as well as Physico-chemical parameters were investigated in six sampling sites of Kano River between June 2014 to May 2015. The pattern of association between measured Physico-chemical parameters were significantly correlated using Pearson Product Moment Correlation and revealed high positive correlation between Total Nitrate and Total Phosphate at site A (.811) and negative correlation between Dissolved Oxygen and pH at site E (-.261). Eigen value of the three variables namely; Temperature, pH and Electrical Conductivity was satisfactory, explaining 73.64% and 70.79% of the total variance in dry season and wet season respectively, other components explained 26.36% and 29.06% noise. Kaiser-Meyer-Olkin in dry season value showed 0.700 degree of common variance is middling bordering meritorious adequacy value while wet season showed miserable degree of common variance value of 0.500. Bartletts' Test of Sphericity showed no difference in wet and dry season with the significant value of p < 0.001. Macroinvertebrates species group frequency distribution of homogeneous set at N 2271 showed Chironomidae subset-7 with the significance of 1.00 highest in harmonic mean value and Planariidae in subset-1 has 0.59 lowest in the value. Generalized Linear Model further revealed the pattern in seasonal variation in the macroinvertebrates data set. The findings were discussed and recommendations made.
Key words: Dendrites, Diversity, Eigen value, Macroinvertebrates, Multivariate, River Kano.

INTRODUCTION

Freshwater ecosystems are among the seriously threatened habitats in the world (Pacheco *et al.,* 2016). During the recent times, the loss of freshwater biodiversity has been accentuated mainly due to changes in land use from human related activities such as deforestation and livestock or arable farming that have resulted in habitat destruction, fragmentation and eutrophication (Boris *et al.,* 2016). Aquatic habitats are adversely impacted by urbanization, deforestation, construction, irrigation, drainage of wetlands and pollution (Fornaroli *et al*., 2016). Freshwater organisms live almost continuously in the water and respond to all environmental stresses, including synergistic combinations of pollutants (Tinotenda *et al.,* 2016). Different biological organisms have their own ecological functioning patterns, integrative representation of the community can provide a comprehensive assessment of ecological status (Xiang *et al*., 2016). Macroinvertebrate based multivariate techniques have been applied widely in developed countries since the 1980s (Diego *et al*., 2016). However, the number of applications has increased markedly in the last 5 years; In Amazon (Dedieu *et al.,* 2015), in Atlantic (Tomi *et al.,* 2016), and Central America (Stefanidis *et al*., 2016).

Multivariate approaches have been used successfully to predict expected invertebrate community structure at the selected sites (Jongseong *et al.,* 2016). Principal Component Analysis (PCA) is a powerful pattern recognition tool that attempts to explain the variance of a large dataset of sampled macroinvertebrates (Stefan *et al*., 2016). PCA technique extracts the eigenvalues and eigenvectors from the covariance matrix of original variables, and is designed to transform the original variables into new, uncorrelated variables (3D-axes), called the principal components, which are linear combinations of the original variables (Jennifer *et al.,* 2014). It reduces the dimensionality of the dataset by explaining the correlation amongst a large number of variables in terms of a smaller number of underlying factors, without losing much information (Wen-Ping *et al*., 2016).

Another multivariate statistical tool such as, Hierarchical Agglomerative Cluster Analysis (HACA) have been recently applied in ecological studies to investigate the factors underlying the distribution of stream macroinvertebrates (Ruaro and Gubiani, 2013; Yuxiao *et al*., 2015). Streams can be defined as hierarchically organized systems, incorporating different spatial levels, such as basin, segment, reach and microhabitat. Hierarchical framework at multiple spatial levels can affect the stream macroinvertebrates (Fornaroli *et al*., 2016).

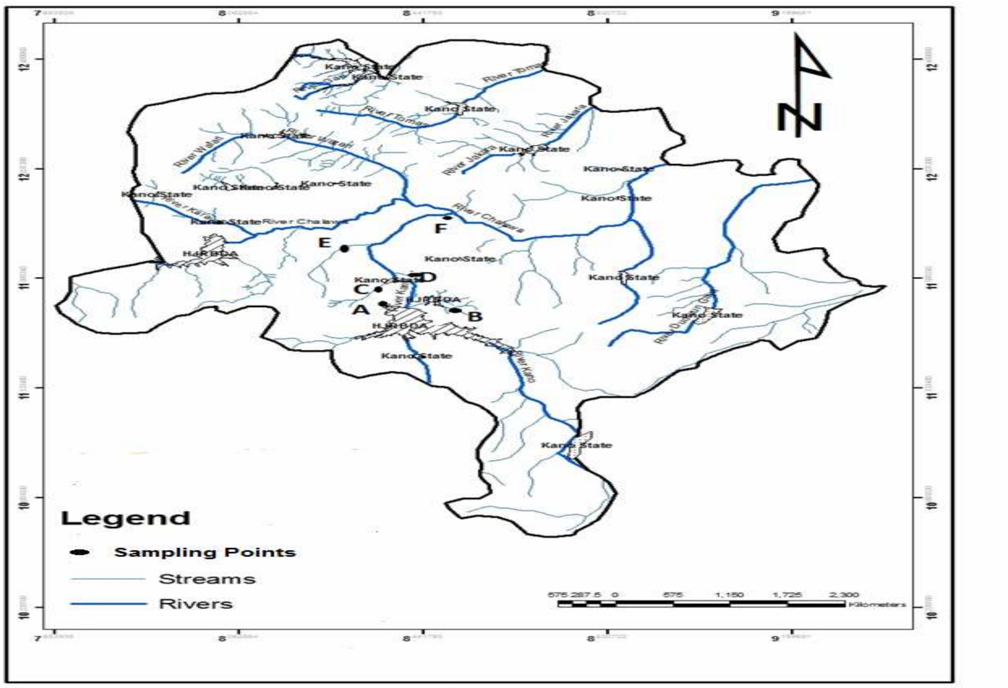
At lower spatial level, the tool cluster similar variability of macroinvertebrates assemblage structure, species identities, and functional feeding group composition in relation to stream land use activities (Tinotenda *et al.,* 2016). However, Alexander *et al*., 2016, pointed that, HACA tool assessed taxonomic distance among species using Euclidean distance in species space gradient to describe changes in diversity over time. Limitations of most multivariate applications included the absence of statistical criteria for identifying a priori least and most disturbed sites, failure to account for natural environmental variability, use of redundant metrics, and non-continuous metric scoring (Ruaro and Gubiani, 2013).

The aims of this study are (1) to recognized the associations and pattern in biological and Physico-chemical variables within the multivariate data set (2) to rotate the multivariate data cloud and extract the important components using PCA (3) to find the harmonic mean group of sampled macroinvertebrates frequencies to examine variability of macroinvertebrate assemblage structure.

MATERIALS AND METHODS

Study Area

Kano state is located between latitude 10° $30'$ to 12° $40'$ N and longitude 7° $40'$ and 9° $30'$ E. The climate is classified as tropical dry and wet type. Kano River is located on the Southern part of Kano between the latitude 10° $10'$ to 11° $50'$ N and longitude 8° $17'$ and 8° $40'$ E (Olofin, 1985). It has a confluence with Challawa River at Tamburawa Bridge and is about fifty-eight kilometers (58.8km) in length from Tiga dam discharge outlet. It flows southeast to north meandering to north east at confluence (Figure 1).



Source: Carto. Geography Department, BUK 2015

Fig. 1: Map of the study area showing sampling points

Sites were selected spatially using a randomized systematic procedure described by Olsen and Peck (2008) and USEPA (2012). Sites were delineated as A, B, C, D, E and F along the river streams from the upper reaches down to the confluence point.

Sample collection

The macroinvertebrates were sampled in three sampling occasion monthly from June 2014 - May 2015 using the standardized kick-net method as described in Gabriels *et al*. (2010). The samples were fixed in the field with 40% formalin and taken to Bayero University Kano laboratory in individual sites labeled plastic containers. In the laboratory, the samples were washed, sorted, and all individuals were identified mostly to family with the aid of taxonomic keys of Merritt *et al*. (2008) and Mugnai *et al*. (2010). Sampling was conducted in early morning hours along the river reaches in triplicate each month, ranges for physical variables determined and recorded at the sampling sites. Water Temperature ($^{\circ}$C) was measured *in situ* using thermometer as described by APHA, (2012) and pH was determined using dip-inn mobile battery operated pH meter, as described by Maiti (2004). Dissolved Oxygen (mg/L) was determine using 200 model DO meter as described by Maiti (2004). Electrical Conductivity (µS) was measured using Jenway conductivity meter model 4010. Alkalinity (mg/L) was determined from the 250ml of river water sample following titrimetric method of Maiti (2004). Total Nitrate (TN) and Total Phosphate (TP) were determined using multiparameter ion specific meter (HANNA C-2000 model) as described by HANNA Instruction Manual. Five days incubation method was employed to determine the Biochemical Oxygen Demand (BOD) level of the water samples as described by Okafor (1985) and Maiti (2004).

Data Analysis

The analytical procedures were that, identified taxon count from sites were recorded as well as physical and chemical parameters. Correlations between Physico-chemical parameters were computed using Pearson's Product Moment Correlation (PPMC) following Mukaka (2012) and Principal Component Analysis (PCA) were conducted to test the sampling adequacy using Kaiser-Mayer-Olkin (KMO) and Battelet's Test of Sphericity (BTS) of the multivariate data set in wet and dry season Robert *et al*. (2012). Estimated Mean Marginal (EMM) for macroinvertebrates count from six sites conducted between season and species. All data analyses were carried out using IBM-JAVA SPSS version 21 (2012).

RESULTS AND DISCUSSION

Table 1 presents the mean values of measured Physico-chemical variables, Temperature ranged from 16.30°C to 36.30°C, due to differences in the time of sampling and prevailing ambient temperature and season. The lowest conductivity was observed at site C in the month of January (46.30µS), while the highest was at the site F in the month of May. Site F is characterized by confluence point between Kano River study sites and the Challawa River. The pH ranged from 5.30 to 8.30. Minimum Alkalinity value was observed at Site A, an upstream outlet location in the month of May. However, the highest Alkalinity of 5.0mg/L was recorded in November at Site F downstream this may be due to hydrodynamics of the river according to Stefen *et al.,* (2016). Dissolved oxygen of the river water recorded the mean of value of 5.4528 mg/l, the related value to USEPA (2012), with the mean deviation value of ±.67988 mg/l. Dissolved oxygen ranged from 2.70 mg/L to 9.80 mg/L. Minimum recorded value of TN was 0.7mg/L at Site A in the month of June, beginning of the rainy season, to maximum value of 4.90mg/L at Site F in October the rainy season category month. Similarly, maximum TP value was of 5.00mg/L recorded in October at Site F. This indicate the association between the measured elements. BOD_5 was recorded and indicated the maximum value of 3.40 at Site F in August, the minimum of 0.70 was at Site C in the month of January.

Physico-chemical variables recorded from the sampling sites were correlated to ascertain the degree of the association between them (Table 2). Correlation between TN and TP revealed a strong relative values of .811, .737, and .727 at Sites A, B, and E respectively according to Guildford rule of thumb (Dziuban, *et al*. 1974; Mukaka, 2012). However, Site C, D and F showed a moderate rule. These differences could be due to agricultural activities bordering the sampling sites (Minar *et al*., 2016). Temperature and Conductivity revealed some associations at Site A, B, C, E and F with almost no relationship between them at site D. Correlation values between pH and Alkalinity revealed a significant associations at all sites with moderate rule, corroborating the conclusion of Charles (2015) that variables significantly correlate with each other do so because they are measuring the same thing.

In total, 2271 macroinvertebrates were sorted and identified during the twelve month of sampling period, which belong to 19 different families. Homogeneity among the sampled quantities were computed for means homogeneity sets among the invertebrate groups for significances (Table 5). Dry and wet season values were compared for higher estimated marginal means of species abundance (Fig. 3). Chironomidae was the most abundant family succeeded by Nemouridae and Simuliidae in total of 555, 253 and 234 animals respectively. This corroborates the findings of Boggero, *et al*. (2006) and Al-Shami, *et al*. (2010). However, lowest families are Planariidae*,* Oligochaeta and Agriidae 11, 31, and 38 respectively . Different macroinvertebrates composition could be due to site different physical habitat characteristics, the key determinants influencing the structure and composition of aquatic assemblages (Allan, 1995; Alexander, *et al*. 2016). The number presence of macroinvertebrates count in the sampling sites was based on the rule of Barbour *et al*. (1999), Mereta *et al*. (2013), and Helson and Williams (2013). Chironomidae and Oligochaeta assemblages varied significantly among the collection sites with the set significant values of 0.59 and 1.000 respectively. Their assemblages in relation to the environmental variables, indicating the need to use both groups in biomonitoring studies (Beatriz *et al.,* 2014). Taxon homogeneous means group ranked Platycnemididae in subset of 4 with the significant value of 0.52 which significantly differ from Simuliidae and Nemouridae in mean subset of 6.

Multivariate data cloud from environmental space in dry and wet season was rotated using PCA- Varimax with Kaiser normalization (Table 3) (Kaiser, *et al*., 1977; Kevin, 2009; Fernorali *et al*., 2016). Component rotation of the dry season data showed 0.700 degree of common variance which is merit, while wet season data showed miserable value of 0.500 in conformity with Charles (2015), table of degree of common variance. Bartlett's' Test of Sphericity showed no difference in wet and dry season with the significance difference value of $p < 0.001$. This revealed the computed variables are statistically adequate and are multivariate normal (Alexander *et al.* 2016), also Bartlett's test value of 0.500 indicate relationships among the variables are linear with absence of outliers among the cases (Diego *et al*. 2016). The variables; Temperature, pH and Conductivity were satisfactory, explain the factor loading of the Eigen values 73.64% and 70.94% of the total information in dry and wet season respectively which revealed communality among the variable (Maria *et al*. 2015). Others: Alkalinity, Dissolved Oxygen, Total Nitrate, Total Phosphate and Biochemical Oxygen Demand explained only 26.36% and 29.06% noise (Diego *et al*. 2016). Table 4, revealed further the relativity between variables Eigen values from the sampling sites using Cattells' Scree tool and Figure 2 showed visual representation of the information component number - Eigen value relation of all the sites. As the component number increases the Eigen value decreases, the relationship which explains the number of factors to retain (Cattell, 1966; Ladesma and Pedro, 2007).

Therefore, for PCA tool to be effective, measurements of components: Temperature, pH and Conductivity is only needed rather than all the 8 measurements, as concluded by Stuart *et al.* (2008).

Seasonal variation in the faunal abundance between the dry and wet seasons was examined by applying the Generalized Linear Model (Fig. 3) to compare each set of samples (Baselga and Aruyo, 2009; Robert *et al.,* 2012). Family Chironomidae have the highest representation in dry and wet season with about 50 and 35 Estimated Marginal Means respectively. However, family Agriidae record a lowest value in dry season with almost no difference in seasonal records in Planariidae, Oligochaeta and Hirudidae*.* Seasonal variation in stream macroinvertebrate communities results from myriad life-history differences among the community's constituent taxa including growth, development and voltinism (Robert *et al.*, 2012), water flow and food availability (Delluchi and Peckarsky, 1989; Murphy and Giller, 2000). Streams typically exhibit reduced richness, diversity, and abundances of sensitive' taxa (Cuffney *et al.*, 2010; Roy *et al.*, 2003)

Table 1: Mean Standard Deviation of the Physico-chemical Variables Measured at Selected Sites of Kano River Water

Parameter	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Temp. **(^{0}C)**	26.3167	5.24630	0.61828	16.30	36.30
pH	6.9847	.58998	0.06953	5.30	8.30
Cond. **(µS)**	80.5306	22.35813	2.63493	46.30	155.70
Alkal. **(mg/l)**	3.3458	.67988	0.08012	1.80	5.00
DO **(mg/l)**	5.4528	1.50782	0.17770	2.70	9.80
TN **(mg/l)**	2.4042	1.05663	0.12452	0.70	4.90
T P **(mg/l)**	3.1389	.79675	0.09390	1.60	5.00
BOD_5	1.4847	.54866	0.06466	0.70	3.40

Table 2: Pearson's Product Moment Correlation Values for Measured Physico-chemical Parameters

		Temp	pH	Cond	Alkal	DO	TN	TP	BOD_5
Site A	Temp	1							
	pH	**.360***	1						
	Cond	**.808****	.326	1					
	Alkal	-.010	**.500****	.027	1				
	DO	-.285	-.170	-.285	-.018	1			
	TN	.297	.269	.190	.311	.118	1		
	TP	.266	.180	.045	.151	.072	**.811****	1	
	BOD_5	**.336***	.275	.169	**.396***	.111	.118	.091	1
Site B	Temp	1							
	pH	**.362***	1						
	Cond	**.811****	.325	1					
	Alkal	-.159	**.442****	-.126	1				
	DO	-.253	-.033	-.138	.004	1			
	TN	**.339***	.149	.307	.297	.087	1		
	TP	.138	.136	.057	.279	.103	**.737****	1	
	BOD_5	.180	.212	.172	.111	.157	.201	.135	1
Site C	Temp	1							
	pH	**.380***	1						
	Cond	**.794****	.327	1					
	Alkal	.150	**.512****	.024	1				
	DO	-.220	-.094	-.175	.112	1			
	TN	**.350***	.127	**.407***	.253	.143	1		
	TP	.099	.126	.065	.220	**.346***	**.635****	1	
	BOD_5	.187	**.484****	.053	**.348***	.248	.078	.236	1
Site D	Temp	1							
	pH	.079	1						
	Cond	.060	.317	1					
	Alkal	-.014	**.578****	-.031	1				
	DO	-.041	-.060	-.161	-.106	1			
	TN	-.087	.182	**.398***	.078	.042	1		
	TP	-.083	.312	.157	.293	-.035	**.593****	1	
	BOD_5	.078	**.335***	.094	.256	-.112	.055	.132	1

Table 2 continue

	Temp	1							
	pH	.188	1						
	Cond	**.845****	.157	1					
Site E	Alkal	.122	**.573****	.060	1				
	DO	-.171	-.261	-.135	-.045	1			
	TN	**.461****	.323	**.333***	.274	.033	1		
	TP	.232	.206	.071	.265	.230	**.727****	1	
	BOD_5	.235	.358*	.056	**.365***	.244	.052	.152	1
	Temp	1							
	pH	**.405***	1						
	Cond	**.678****	.298	1					
Site F	Alkal	.044	**.481****	.057	1				
	DO	-.228	-.179	-.143	-.123	1			
	TN	**.578****	.359*	**.438****	.281	-.110	1		
	TP	.178	.324	.237	.227	.141	**.643****	1	
	BOD_5	.077	.200	-.107	-.086	.238	.066	.211	1

∗Correlation is significant at the 0.05 level.
∗∗Correlation is significant at the 0.01 level
Bold Type: Represent significance

Table 3: Principal Component Analysis of Physico-chemical Variables from June 2014 - May 2015

		Parameters							
Season	**PCA values**	**Temp**	**pH**	**Cond**	**Alkal**	**DO_2**	**T N**	**T P**	**BOD_5**
Dry	KMO	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
Wet	KMO	0.512	0.512	0.512	0.512	0.512	0.512	0.512	0.512
Dry	BTS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wet	BTS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dry Eigen values	Total	3.20	1.66	1.02	.87	.58	.29	.23	.15
	% of Variance	40.05	20.83	12.76	10.85	7.21	3.58	2.836	1.87
	Cumulative %	40.05	60.88	73.64	84.49	91.71	95.29	98.13	100.00
Wet Eigen values	Total	2.82	1.84	1.01	.88	.63	.47	.24	.11
	% of Variance	35.30	23.01	12.63	11.05	7.87	5.82	2.99	1.32
	Cumulative %	35.30	58.31	70.94	81.99	89.86	95.69	98.68	100.00

Significant at > 0.5 (Degree of common variance)
Significant p< 0.000 level

Table 4: Relativity Between Physico-chemical Variables Values for the Sampling Sites using Cattells' Scree Tool

		Sites Eigen values					
Variable number	**Rotated component**	**A**	**B**	**C**	**D**	**E**	**F**
1	**Temp**	2.751	2.554	2.707	2.323	2.780	2.857
2	**pH**	1.696	1.748	1.768	1.395	1.607	1.451
3	**Cond**	1.328	1.177	1.393	1.145	1.378	1.216
4	**Alk**	0.958	1.068	0.785	0.962	1.080	0.909
5	**DO_2**	0.591	0.718	0.550	0.789	0.485	0.678
6	**TN**	0.410	0.389	0.370	0.756	0.369	0.404
7	**TP**	0.154	0.187	0.272	0.354	0.203	0.332
8	**BOD_5**	.0114	0.158	0.156	0.275	0.098	0.155
	Total	**7.999**	**8.001**	**7.999**	**8.000**	**8.002**	**8.002**

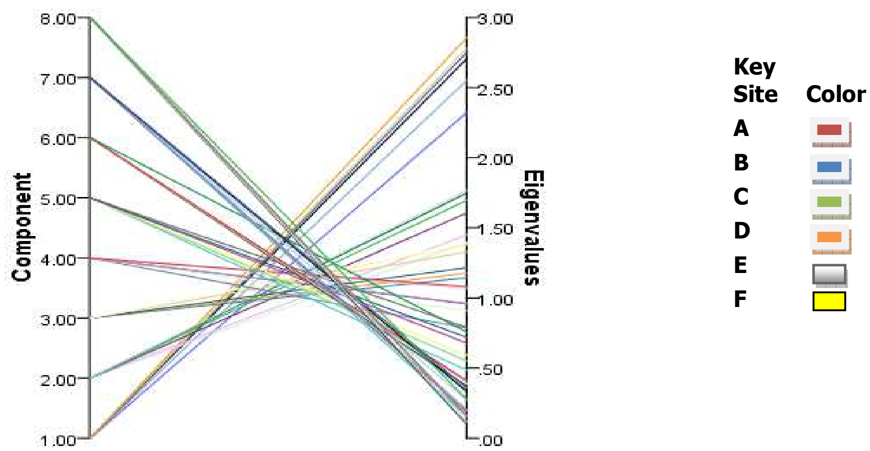


Fig. 2: Scree Cobweb plot for Sites Eigen values and component numbers

Table 5: Harmonic mean group frequency distribution of the Macroinvertebrates sampled sets

	Subset						
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Planariidae	.9167						
Lymbricoidae	1.6667						
Hydroptilidae	2.0000						
Agriidae	2.2500	2.2500					
Gammaridae	3.0000	3.0000					
Oligochaeta	3.5000	3.5000					
Vivaltidae	4.1667	4.1667					
Hirudidae	5.2500	5.2500					
Batidae	5.7500	5.7500					
Corixidae	6.0833	6.0833	5.7500				
Platycnemididae	6.6667	6.6667	6.0833	6.6667			
Hydrobidae		7.9167	6.6667	7.9167	7.9167		
Hydrophilidae			7.9167	11.1667	11.1667		
Hydrometridae			11.1667	11.6667	11.6667		
Aphelocheiridae				12.1667	12.1667		
Siplonuridae					12.3333		
Simuliidae						18.1667	
Nemouridae						20.1667	
Chironomidae							44.1667
Sig.	**.059**∗	**.058**∗	**.056**∗	**.052**∗	**.123**∗	**.430**∗	**1.000**∗

Means for groups in homogeneous subsets displayed at N = 2271
∗Significant p > 0.05

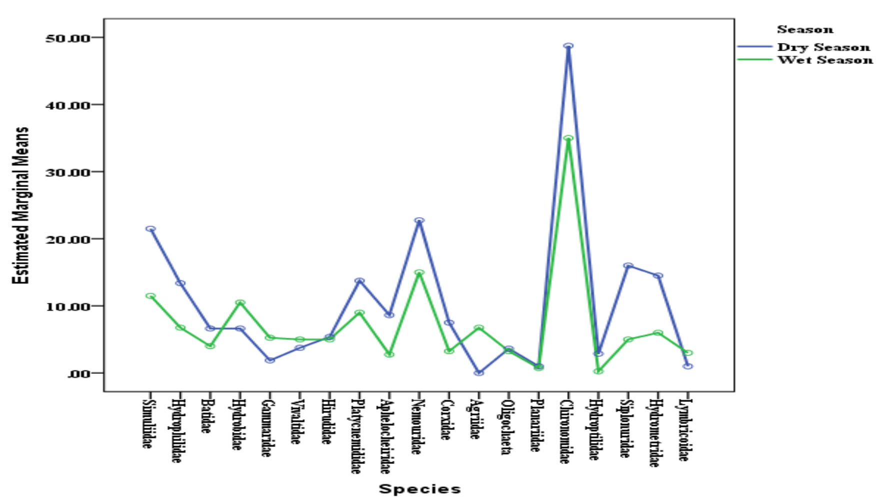


Fig. 3: Estimated marginal means species abundance in dry and wet season

CONCLUSION

From this study, macroinvertebrates' responses towards environmental changes across sites and season is evident. Macroinvertebrates were documented and indentified as gathering collectors - Chironomidae were dominant taxon from all streams in wet and dry season of the study period. Seasonal pattern of variations from aspects of Kano River environment were observed from biological communities samples and evaluated using multivariate tool. The first extracted Eigen value through the third are related to the amount of variation explained as a percentage of the total information within the data set, while the remaining variable explain the trivial amount and might not worth interpreting. PCA, therefore, allows the use of variables which are not measured in the same unit.

RECOMMENDATIONS

It is recommended that multivariate approach to the study of anthropogenic pressures with natural environmental gradients in stream macroinvertebrates can further be investigated using PCA tool. Macroinvertebrates communities inhabiting Kano River streams can further be investigated and classified into Functional Feeding Groups (FFG) using Hierarchical Agglomerative Cluster Analysis (HACA) tool to predict biological water quality indices based on stream macroinvertebrates and environmental parameters.

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