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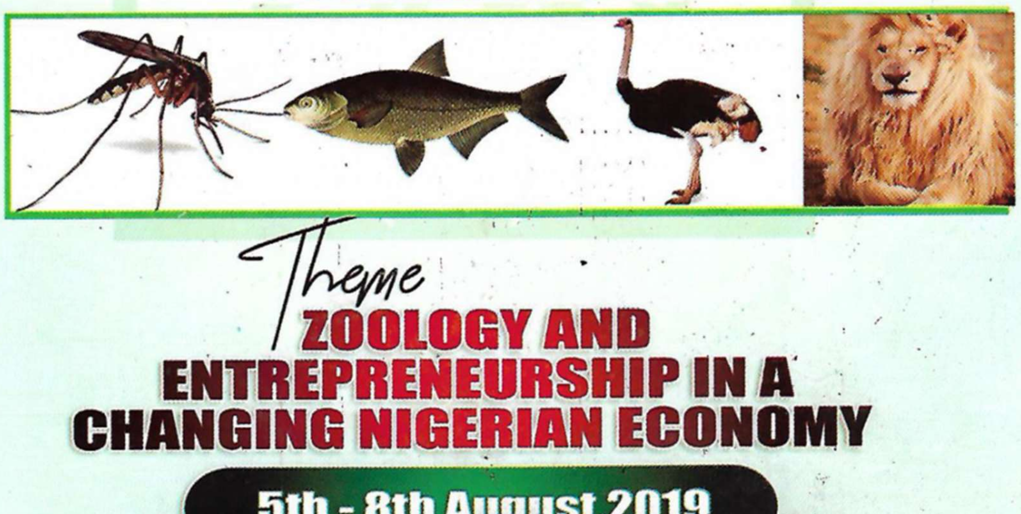
BOOK OF ABSTRACTS



Theme

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THE USE OF MACROINVERTEBRATE INDICATOR SPECIES TO MONITOR ECOLOGICAL CHANGE IN SOME STREAMS IN NORTH CENTRAL NIGERIA

Arimoro F.O*, Keke U.N. and Ayanwale A.V.

Applied Hydrobiology Unit, Department of Animal Biology, Federal University of Technology,
Minna, Nigeria.
*Correspondence f.arimoro@futminna.edu.ng

ABSTRACT

Indicator species have been employed in modern aquatic research for monitoring of ecological changes. In this study, we evaluated the possibility of developing surrogate indicator groups as tools for the conservation and management of the biodiversity of Niger state streams by surveying 15 streams in Niger state for benthic macroinvertebrates and environmental variables as data sets, over a period of 24 months (2016 and 2017). Samples were collected in two locations of reference and impacted sites for each of the streams surveyed. The statistically significant ($p < 0.05$; based on 1000 permutations) indicator species for each of the status classes (reference versus impacted) was detected using the Indicator species analysis/Indicator value method. Hierarchical agglomerative clustering was used to group sites for each sampling status class based on macroinvertebrate community structure. To visually access the multivariate patterns and structures of the macroinveretebrates community composition, non-metric multidimensional scaling (NMDS) ordination was performed. Indval found fifteen species for the reference, seven (7) indicator species for the impacted streams, with the Coleopteran *Hydrophilus* sp., occuring as the keystone species. NMDS revealed that species assemblage had wide dispersal patterns in relation to the sites in both status classes. Canonical Correspondence Analysis revealed that the clear lack of concordance in environmental variables-requirements of the reference species versus the impacted indicator species showed that the two taxa responded to entirely different environmental factors. While this study has provided a reference point and effective tool to monitor environmental changes, community and ecosystem dynamics in Niger state streams, it is therefore advised that other components of freshwater biota be tested for possible use as surrogates in freshwater biodiversity research of these streams.

Keywords: Biodiversity, surrogates, benthic macroinvertebrates, conservation, indicators, species, Niger State.

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Indicator species have been employed in modern aquatic research for monitoring of environmental changes. In this study, we evaluated the possibility of developing surrogate indicator groups as tools for the conservation and management of the biodiversity of Niger state streams by surveying 15 streams in Niger state for benthic macroinvertebrates and environmental variables as data sets, over a period of 24 months (2016 and 2017). Samples were collected in two locations of reference and impacted sites for each of the streams surveyed. The statistically significant ($p < 0.05$; based on 1000 permutations) indicator species for each of the status classes (reference versus impacted) was detected using the Indicator species analysis/Indicator value method. Hierarchical agglomerative clustering was used to group sites for each sampling status class based on macroinvertebrate community structure. To visually access the multivariate patterns and structures of the macroinveretebrates community composition, non-metric multidimensional scaling (NMDS) ordination was performed. Indval found fifteen species for the reference, seven indicator species for the impacted streams, with Coleopteran *Hydrophilus* sp. Occurring as the keystone species. NMDS revealed that species assemblage had wide dispersal patterns in relation to the sites in both status classes. Canonical Correspondence Analysis revealed that the clear lack of concordance in environmental variables-requirements of the reference species versus the impacted indicator species showed that the two taxa responded to entirely different environmental factors. While this study has provided a reference point and effective tool to monitor environmental changes, community and ecosystem dynamics in Niger state streams, it is therefore advised that other components of freshwater biota be tested for possible use as surrogates in freshwater biodiversity research of these streams.

Keywords: Biodiversity, Surrogates, Benthic Macroinvertebrates, Conservation, Indicators species, Niger state.

1.0 INTRODUCTION

Following lack of luxury of requisite resources necessary for biodiversity conservation and surveys, environmental experts and conservationists have made it a duty to develop biological surrogates that would be instrumental in biodiversity prediction and mapping (Heino, 2010). Similarly, so many environmental and ecology experts are thriving with efforts to provide measures that would help in the mitigation of several environmental challenges that are ravaging the world at large, including environmental pollution, habitat loss, outbreak of diseases, climate change, among others. The adoption of monitoring strategies and principles with the capacity to detect such environmental and ecological changes at both stages (early and long term) has been one of the most popular strategies among the various suggested options. Evidences abound about the usefulness of this biological assessment and monitoring strategy in providing robust information, as well as affordable environmental management decisions (Spellerberg, 2005; Siddig *et al.,* 2016). Biodiversity assessment and conservation in a broad-scale pattern have basically employed the use of biological surrogates, and this refers to indicating the biological diversity of a whole metacommunity by using information already established about the biological diversity or taxa richness of a few-known taxonomic groups (Angermeier & Winston, 1997; Paavola *et al.,* 2003). However, how reliable such biodiversity indicators are in conservation and management efforts, especially in freshwater aquatic biotic community has rarely been tested, though rigorously (Paavola *et al.,* 2003).

Indicator species groups with ability to be used in predicting various differences in biodiversity of other taxonomic groups are among the most popular surrogates (Heino, 2010). The indicator species (IS) are those organisms whose presence, absence, or condition gives information about the environmental status (s) or quality of where they are found per time (Bartell, 2006; Burger, 2006; Siddig *et al.,* 2016). The principle of the use of indicator species is driven from the idea that the community abundance, diversity, and rates of growth and reproduction among species totally reflect both short and long term patterns of change and responses of the organisms to the overall effects of environmental changes (Bartell, 2006; Siddig *et al.,* 2016). The presence or absence of healthy populations of these species indicators gives information about a unique environmental characteristic. The dearth of understanding of the cumulative synergistic effects of pollution on aquatic ecology, following lack of robust ecological information by the use of environmental variables alone for water quality assessment has led to the reliance on the IS. Though the use of IS as ecological predictors and indicators of environmental and climatic changes have proofed to be cost-effective and very reliable tool, the major pit-fall and draw-back lie on the rationale and methods of selecting the specific indicators and as well as elucidating the environmental relationships between the specified IS and their various specific applications.

The adoption and use of the indicator species for a broad suite of environmental assessment and ecosystem monitoring has been common in recent publications. For example, a review of the IS use in the world by Caro (2010) and Siddig *et al.* (2016) revealed that: about 42 % (which was the most frequent use) of publications of its use was for ecosystem integrity and health evaluation; about just 4 % of the publications was on the use of IS as signals of early warnings of environmental changes; 18 % of the publications addressed the use of IS in monitoring changes in the chemical composition of the environment, especially regarding effects of pollution and environmental contamination; 16 % of the publications focused on the use of IS in the evaluation of human-induced disturbances and impact assessment. Niger State of Nigeria is surrounded by several freshwater bodies that serve as habitat for macroinvertebrates. However, anthropogenic impacts along the banks, most notably in downstream regions, have resulted to river pollution. Industrial and anthropogenic activities, fishing, quarrying, sprawling urbanization, and water pollution are common issues around these rivers that have threatened the quality of freshwater in the area. Water quality of these rivers decreases as it approaches downstream affecting macroinvertebrate assemblage structure and composition. Given the pressing need to monitor community and ecosystem dynamics of these streams, this research was birthed to provide a surrogate for monitoring environmental health and integrity of these streams, with the ultimate goal of conserving and preserving biodiversity of the region.

2.0 MATERIALS AND METHODS

2.1 Study area and sampled rivers

The study area covers the range of 9°N to 10°N and 6°E to 7°E (Figure 1). We sampled 15 streams selected from Niger State, Nigeria. The characteristics of the study area is that of the tropical climate of two distinct seasons: the dry season (November–March) and the wet season (April–October). Visible human activities of this study area included forestry and agricultural practices, sand dredging, farming, fishing, gold mining, indiscriminate defaecation, among others. Sampling for both benthic macroinvertebrates and environmental predictors was carried out in 24 months (2016 and 2017) in two locations of reference and impacted sites for each of the streams surveyed. Basically, sampling was conducted four times within a period of one year from each of the sites, representing both seasons (rainy and dry). The process was repeated in the following year. In all cases, environmental predictors assessment was done simultaneously with benthic macroinvertebrates sampling. We followed the process of Leibold *et al.* (2004) in ensuring that we were studying some sets of interacting species by sampling within across the streams within a short period of time.

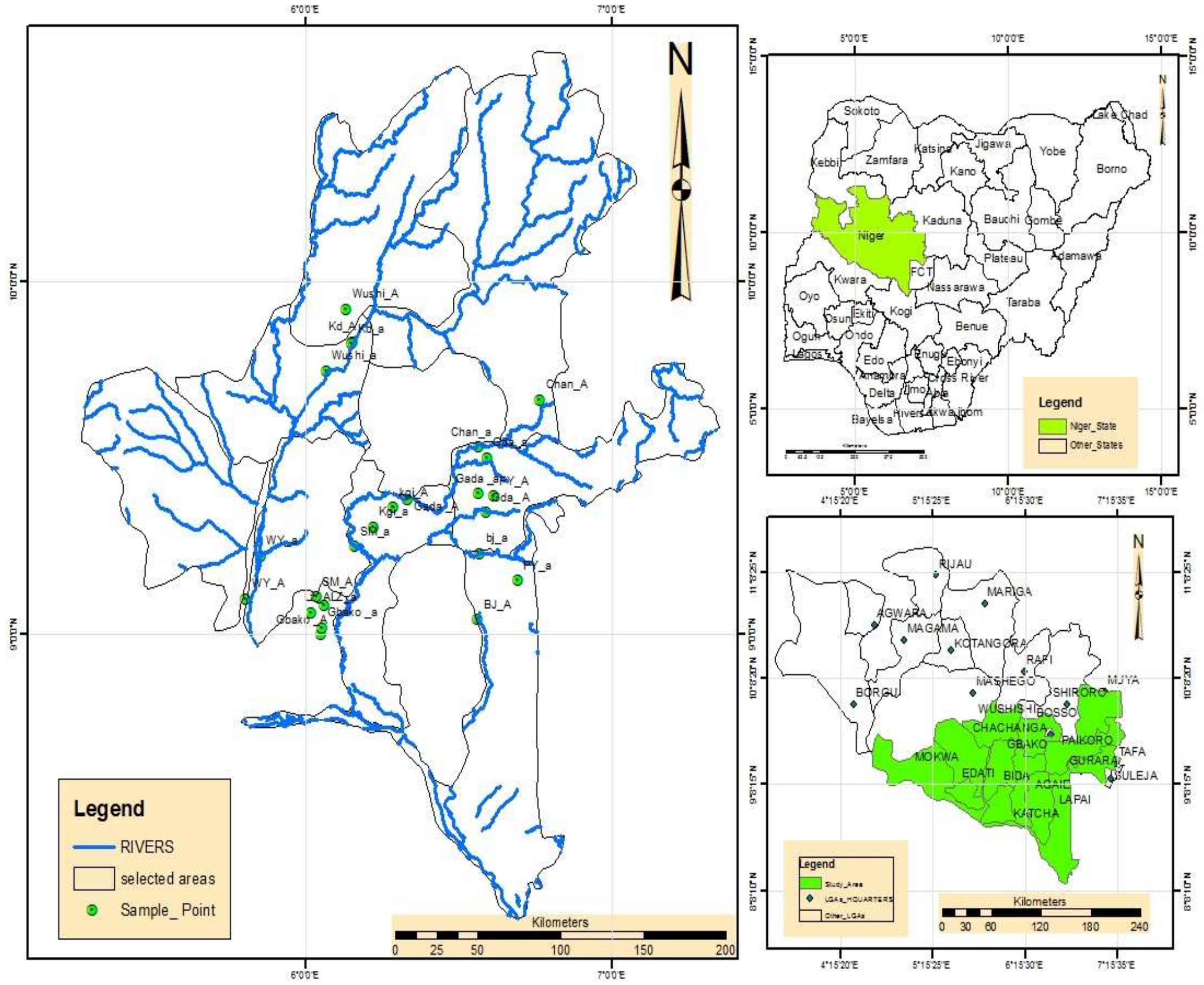

Fig. 1: Map of Nigeria (B) showing Niger state (C) and the sampling locations (A)
Source: Department of, Federal University of Technology, Minna (2017).

Water sampling for Environmental Variables

Water samples were collected monthly over a period of 24 months (2016 and 2017) at each station. On site, during each sampling event, subsurface water temperatures, dissolved oxygen (DO), temperature-corrected electrical conductivity (EC), total dissolved solids (TDS), pH, depth and flow velocity were measured. A mercury-in-glass thermometer was used for measuring temperature. A HANNA HI 9828 multi-probe metre manufactured by HANNA instruments was used for measuring values of DO, EC, TDS and pH. Average mid-channel water velocity was measured in three replicates by timing a float as it moved over a distance of 10 m (Gordon et al. 1994). Depth was measured in the sample area using a calibrated rod. Water samples were collected in 1-l plastic acidwashed bottles and transported to the laboratory in a cooler box containing ice. In the laboratory, water samples were analysed for nitrate, BOD5, sulphate, phosphate and sodium according to APHA (1998) methods. Analysis of all samples commenced within 24 h of sampling. Substratum composition in each 25- m sampling reach was estimated visually as percentage of silt, sand, stone and clay including percentage macropytes, coarse particulate organic matter (CPOM) and woods/logs (Ward 1992).

Macroinvertebrate sampling and processing

At each station, using a 0.09-m2 surber sampler with a 250-µm mesh, macroinvertebrates were collected from a 100-m stream reach comprised of three microhabitats, i.e. pools, riffles and runs, identified according to Jeffries and Mills (1990). To avoid bias due to spatial variations or patchiness, three random samples were collected from each of the three microhabitats by establishing a transect at each sampling reach with five equally spaced points from which a sampling point was selected using random numbers. This procedure was replicated three times for each microhabitat, making nine samples per reach and then the replicates pooled to form one composite sample per station per sampling event. Samples from the three microhabitats per sampling event per site were pooled into one composite sample to avoid artificial effects of pseudo-replication since the reason for the replicate samples from each microhabitat was to ensure that all microhabitats were adequately sampled. The samples were preserved in 10 % formaldehyde solution and transported to the laboratory for sorting and identification. In the laboratory, samples were washed through a 250-µm mesh sieve, sorted and counted using a stereomicroscope. Sorted macroinvertebrates were identified to the lowest taxonomic level possible, mostly genus, according to Merritt and Cummins (1996), Day et al. (2002) and De Moor et al. (2003). Reference was also made to the taxonomic lists of species known to be present in Nigeria (e.g. Arimoro and James 2008; Arimoro et al. 2012).

Data Analysis

The indicator species that were statistically significant ($p < 0.05$; based on 1000 permutations) for each of the status classes (reference versus impacted) was detected using the Indicator species analysis/Indicator value method (IndVal; Dufrene and Legendre, 1997). The product of a species relative abundance and is frequency equals the indicator value of that species, and this indicator value ranges from 0 (which depicts no indication) to 100 (which depicts perfect indication) (Petersen and Keister, 2003). The characteristics of a perfect indicator should include the following: the perfect indicator belonging to a specific group should be faithful and unique, and should not occur in any other group (McCune and Grace, 2002). In this study, any species occurring in any specific group and exhibited any indicator value that is higher than was seen in any other group was designated as a very eritable, reliable, and ideal indicator species of that specific group. It identified the indicator specie whose between-group variation was more than the variation ordinarily expected by chance, and their degree of significance was tested by employing the technique of Monte Carlo randomisation (Legendre & Legendre, 1998). The variation in the values of indicator ranges from 0 to 100, and the highest value is reached when every individual of a particular species is seen occuring in sites of same group, and also when the species are also seen occuring in all the sites of that particular group. The advantages of using IndVal over TWINSPAN include the following, among others: the basis of IndVal is comparisons based on within-species, regardless of the occurrences of other species. Furthermore, it is a more robustful tool in considering differences in observed in the various sizes of a group and their abundances of several species. In detecting the indicator species of a group, IndVal portrays more degree of sensitivity than the TWINSPAN at detecting the indicator species (Dufreˆne & Legendre, 1997). It is in the light of the above features the IndVal possesses that it is attached more superiority than the other conventional techniques of detecting indicator species (McGeoch & Chown, 1998).

Cluster analysis is a multivariate method with the ultimate aim of classifying or grouping samples or sites in order of their similarity such that samples, sites or replicates of a sample with similar biological community composition form distinct clusters from those of other sites or samples. Hierarchical agglomerative clustering was used to group sites for each sampling status class based on macroinvertebrate community structure. Hierarchical agglomerative clustering usually uses a similarity matrix in fusing the samples into groups, after which it proceeds with onward fusing of the groups into larger clusters, beginning with the ones whose mutual similarities are highest before gradually reducing the similarity level where the groups are formed and resulting in a single cluster containing all samples (Clarke and Warwick, 1994). Results that emanate from hierarchical clustering are pictorially presented in dendrograms, where the full sets of samples are represented by the x-axis, while the samples similarity levels are represented in the y-axis.

To visually access the multivariate patterns and structures of the macroinveretebrates community composition, non-metric multidimensional scaling (NMDS) ordination was performed using the metaMDS function in the vegan package. NMDS as an ordination method is based on ranked distances. It is, therefore, exhibits high suitability for the analyses of ecological data for multiple reasons. NMDS deos so well with dataset that are not distributed normally, with discontinuous scales, or dataset whose zero values are so many (McCune and Mefford, 1999).

CCA, being an analysis built on multivariate statistics is usually employed in the elucidation of the details of the relationship between the community structure and the environmental predictors (ter Braak and Verdonschot, 1995). It is a constrained form of ordination technique that is used to simultaneously analyse both species metrics and environmental variables data by the combination of ordination and multiple regression. (Ter Braak, 1995). CCA is frequently employed when the aim is about determining the environmental predictor with that is important in influencing the community structure of the species metrics. In this study, CCA was employed in the elucidation of the degree of relationship between benthic macroinvertebrate scommunity sreucture and the environmental predictors/variables with the ultimate aim of revealing the environmental variables that were influential in the resultant assemblage structure in each of the status classes. The determination of the environmental axis that has significant correlation with the species metrics was done with a Monte Carlo permutation (with 199 random permutations).

Results

Indicator value analysis (Indval) separated the reference streams from the impacted streams. Indval found fifteen species for the reference streams and those species were: Coleopteran *Hyphydrus* sp., *Dysticus* sp., and *Hydrocanthus*, sp.,; Dipteran *Tanytarsus* sp.; Ephemeropteran *Bugilliesia* sp., *Tricorythus* sp., *Thraulus* sp., *Crassabwa* sp.; the Decapoda, *Macrobrachium dux*; the Odonata, *Cordulia* sp., the Arachnida, *Encentridophorus spinifer*; Hemipteran *Naboandelus africanus*; Tricopteran *Leptonema* sp.; Hemipteran *Ranatra* sp.; and the Platyhelminthes, *Dugesia* sp.. Opposite, the Indval found seven (7) indicator species for the impacted streams, which included Coleopteran *Hydrophilus* sp.; the Dipteran *Pentaneura* sp., *Tabanus* sp., *Culex pipiens*, *Ablabesmyia* sp. and the Arachnida, *Arrenurus damkoehlei*. All these indicator species as well as their respective Indicator values and P value ($P < 0.05$) are presented in Tables 1a and 1b. The overall total indicator abundance for reference stations was 1137 out of the overall abundance of 9740 (Table 2a). This constituted for about 12% of the overall abundance of the reference stations (Figure 1a). Similarly, the overall indicator abundance for the impacted stations was 1016 individuals out of the overall abundance of 13349 individuals sampled from the impacted sites. This number represented only about 8% of the entire abundance for the impacted stations. Following, the Coleoptera, *Hypydrus* sp. was the best indicator species for reference streams (Indicator value = 0.749; $P = 0.001$), jointly followed by the Coleoptera, *Dysticus* sp (Indicator value = 0.589; $P = 0.002$) and the Dipteran *Tanytarsus* sp. (Indicator value = 0.576; $P = 0.002$). For the impacted streams, the best two indicators were the Coleopteran *Hydrophilus sp.* (Indicator Value = 0.715; $P = 0.01$) and the Dipteran *Pentanuera* sp. (Indicator value = 0.639; $P = 0.09$).

The flagship species (specific stream-based species) and umbrella species (universal species) of both the reference and impacted sites are represented in Plates 1 to 4. *Hyphydrus* sp. was the indicator species that was characteristic of, and dominant across all reference sites (Umbrella species). Similarly, *Hydrophilus* sp. was the indicator species that was characteristic of, and dominant across all impacted sites (Umbrella species) Site linkages of indicator species occurrence showed clear connections in indicator species across streams in both status classes (Figures 2a and 2b). NMDS showed that these species assemblage had wide dispersal patterns in relation to the sites in both status classes. (Figures 3a and 3b). Both cluster dendrogram and NMDS plots visually showed the general pattern of continuous variation of community structure, although the NMDS showed more discrete variation in community structure.

The eigenvalues of the first three CCA axes for the reference streams were 0.384, 0.268, and 0.207, accounting for 38 %, 26 %, and 21 % of variation, respectively, in the reference indicator species data. Likewise, the eigenvalues of the first three CCA axes for the impacted streams were 0.382, 0.371, and 0.223, accounting for 29 %, 28 %, and 16 % of variation, respectively, in the impacted indicator species data. All CCA analysis showed significant relationships ($P < 0.05$ in Monte Carlo permutations) between the species data and explanatory variables (Tables 3a and 3b). Significant explanatory variables that were important in structuring macroinvertebrates species indicator assemblage structure of the reference sites included the flow velocities, dissolved oxygen, conductivity, and pH while significant explanatory variables that had influence in indicator speaks assemblage of disturbed/impacted stations were dissolved oxygen, BOD, nutrients (nitrates and phosphates), and temperatures

Table 1a: Indicator species (15) of the reference systems identified by Indicator value method (IndVal) at P < 0.05 significance level

Order	Species	Indicator Value	P value
Coleoptera	*Hyphydrus* sp.	0.749	0.001 ***
Coleoptera	*Dysticus* sp	0.589	0.002 **
Diptera	*Tanytarsus* sp.	0.576	0.002 **
Ephemeroptera	*Bugilliesia* sp	0.559	0.020 *
Ephemeroptera	*Tricorythus* sp.	0.550	0.010 **
Coleoptera	*Hydrocanthus* sp.	0.548	0.002 **
Ephemeroptera	*Thraulus* sp.	0.546	0.010 **
Decapoda	*Macrobrachium dux*	0.517	0.004 **
Odonata	*Cordulia* sp.	0.496	0.024 *
Arachnida	*Encentridophorus spinifer*	0.483	0.010 **
Hemiptera	*Naboandelus africanus*	0.483	0.011 *
Tricoptera	*Leptonema* sp.	0.476	0.024 *
Hemiptera	*Ranatra* sp	0.458	0.034 *
Platyhelminths	*Dugesia* sp.	0.447	0.024 *
Ephemeroptera	*Crassabwa* sp	0.390	0.046 *

Table 1b: Indicator species (7) of the impacted systems identified by Indicator value method (IndVal) at P < 0.05 significance level

Order	**Species**	**Indicator value**	**P value**
Coleoptera	*Hydrophilus* sp.	0.715	0.001 ***
Diptera	*Pentaneura* sp.	0.639	0.009 **
Oligochaeta	*Stylaria lacustris*	0.628	0.026 *
Diptera	*Tabanus* sp.	0.516	0.008 **
Diptera	*Culex pipiens*	0.483	0.015 *
Diptera	*Ablabesmyia* sp.	0.482	0.023 *
Arachnida	*Arrenurus damkoehlei*	0.460	0.030 *

Table 2a: Overall numerical composition of the indicator species across the reference systems

Groups	Species	Composition
Coleoptera	*Hyphydrus* sp.	238
Coleoptera	*Dysticus* sp	200
Diptera	*Tanytarsus* sp.	60
Ephemeroptera	*Bugilliesia* sp	83
Ephemeroptera	*Tricorythus* sp.	72
Coleoptera	*Hydrocanthus* sp.	42

Ephemeroptera	*Thraulus* sp.	42
Decapoda	*Macrobrachium dux*	117
Odonata	*Cordulia* sp.	55
Arachnida	*Encentridophorus spinifer*	28
Hemiptera	*Naboandelus africanus*	40
Tricoptera	*Leptonema* sp.	49
Hemiptera	*Ranatra* sp	53
Platyhelminths	*Dugesia* sp.	15
Ephemeroptera	*Crassabwa* sp	43
	Total indicator abundance	1137
	Overall macroinvertebrate abundance	9740

Table 2b: Overall numerical composition of the indicator species across the impacted systems

Groups	Species	Composition
Coleoptera	*Hydrophilus* sp.	239
Diptera	*Pentaneura* sp.	174
Oligochaeta	*Stylaria lacustris*	289
Diptera	*Tabanus* sp.	116
Diptera	*Culex pipiens*	112
Diptera	*Ablabesmyia* sp.	57
Arachnida	*Arrenurus damkoehlei*	29
	Total indicator abundance	1016
	Overall macroinvertebrate abundance	13349

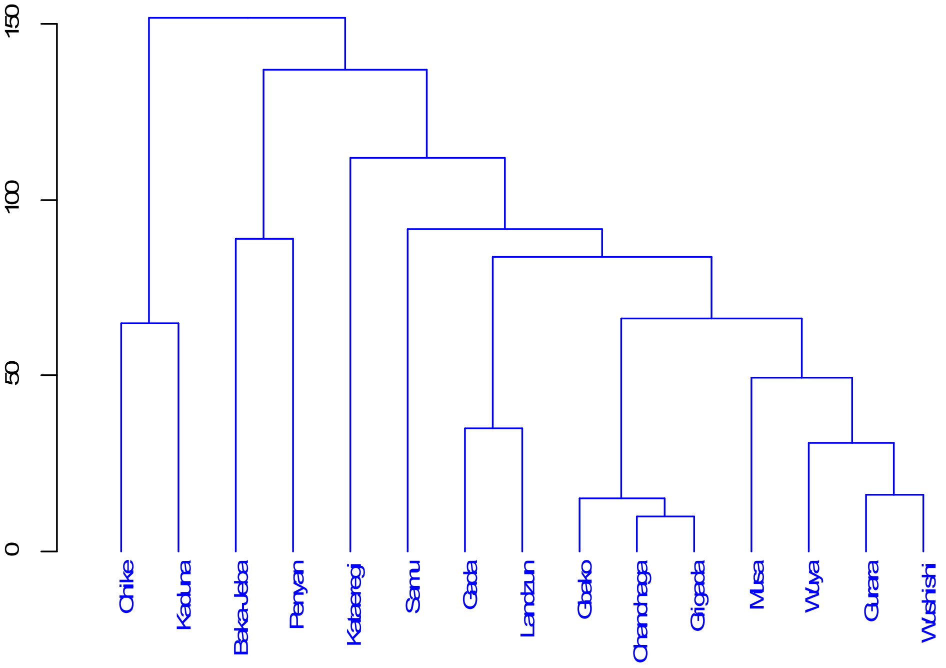

Figure 2a. Cluster dendogram showing site linkages of indicator species occurrence in reference sites.

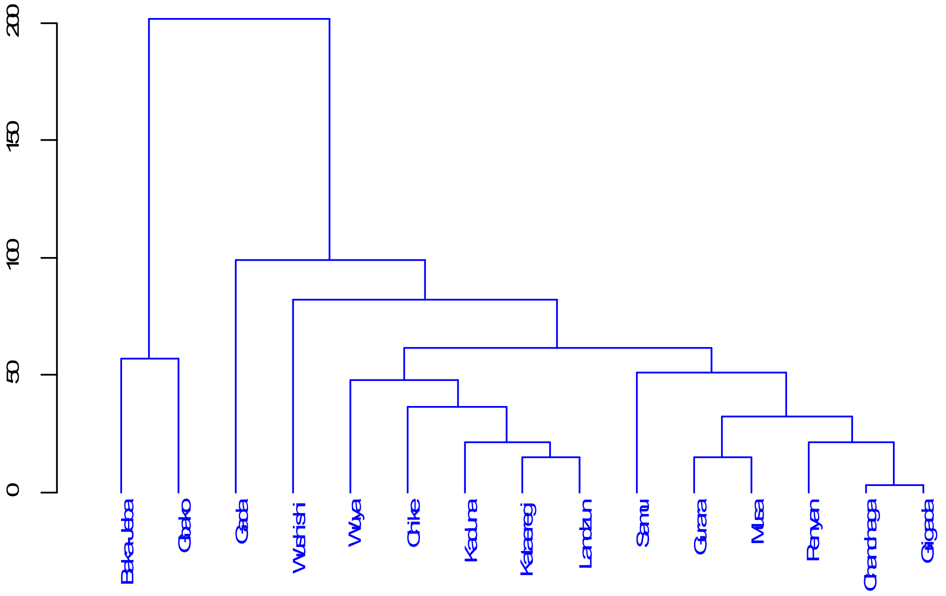

Figure 2b. Cluster dendogram showing site linkages of indicator species occurrence in impacted sites.

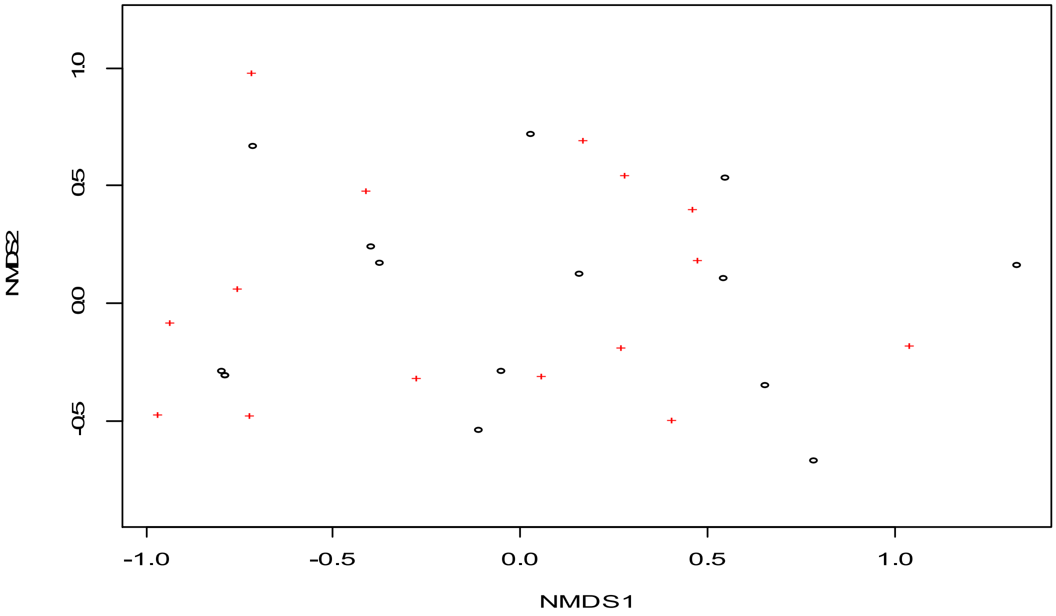

Figure 3a. Non-metric multidimensional scaling (NMDS) of site and species scores relationships of the reference sites. Stress = 0.1619457.

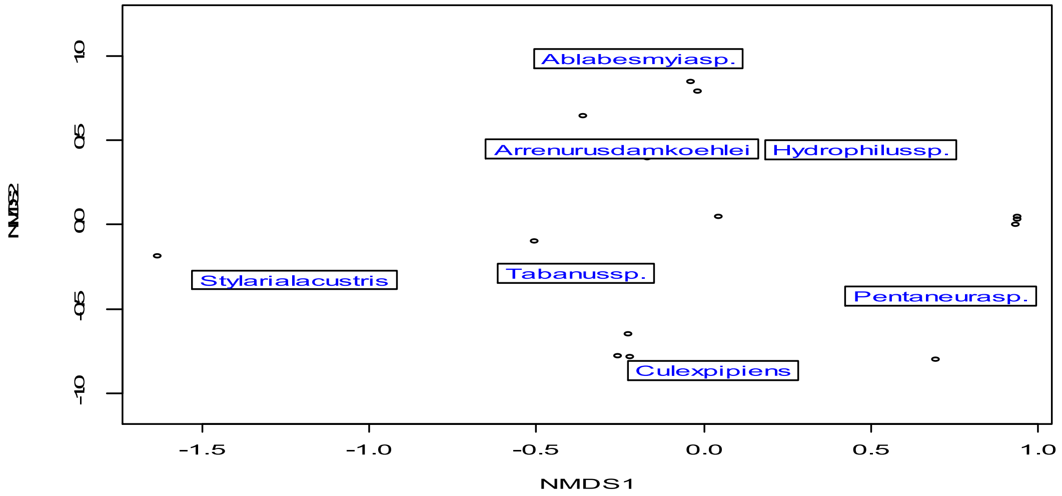

Figure 3b. Non-metric multidimensional scaling (NMDS) of site and species scores relationships of the impacted sites. Stress = 0.06520508.

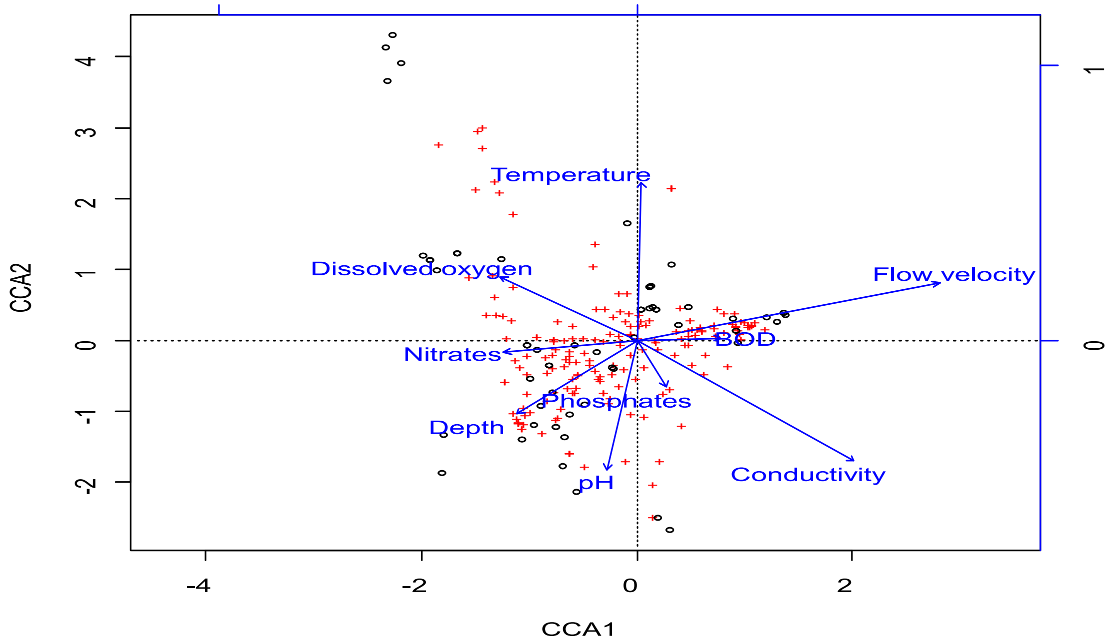

Figure 4a: CCA showing the relationships between the macroinvertebrates indicator species of the reference stations and the environmental variables prevailing at the stations. Open circles = site scores, crosses = species scores; based on symmetric scaling.

Table 3a: Summary of Canonical (Constraint) correspondence analysis (CCA) of indicator species assemblage structure and environmental predictors correlations for reference sites

	Axis 1	Axis 2	Axis 3
Eigen value	0.38390	0.26759	0.20672
Proportion explained (%)	38	26	21
Temperature	0.01161	-0.266476	**0.41863**
Depth	-0.28741	-0.266476	**0.41863**
Flow velocity	**0.72543**	0.209817	0.07259
Conductivity	**0.52034**	**-0.43843**	0.033098
Dissolved oxygen	**-0.32803**	0.232179	-0.11230
BOD	0.20303	0.008112	-0.09570
pH	-0.07239	**-0.467458**	**-0.86744**
Nitrates	-0.31844	-0.042990	-0.09500
Phosphate	0.07107	-0.167448	0.10501

All canonical axes were significant. Values in bold indicate significant difference at $p < 0.05$.

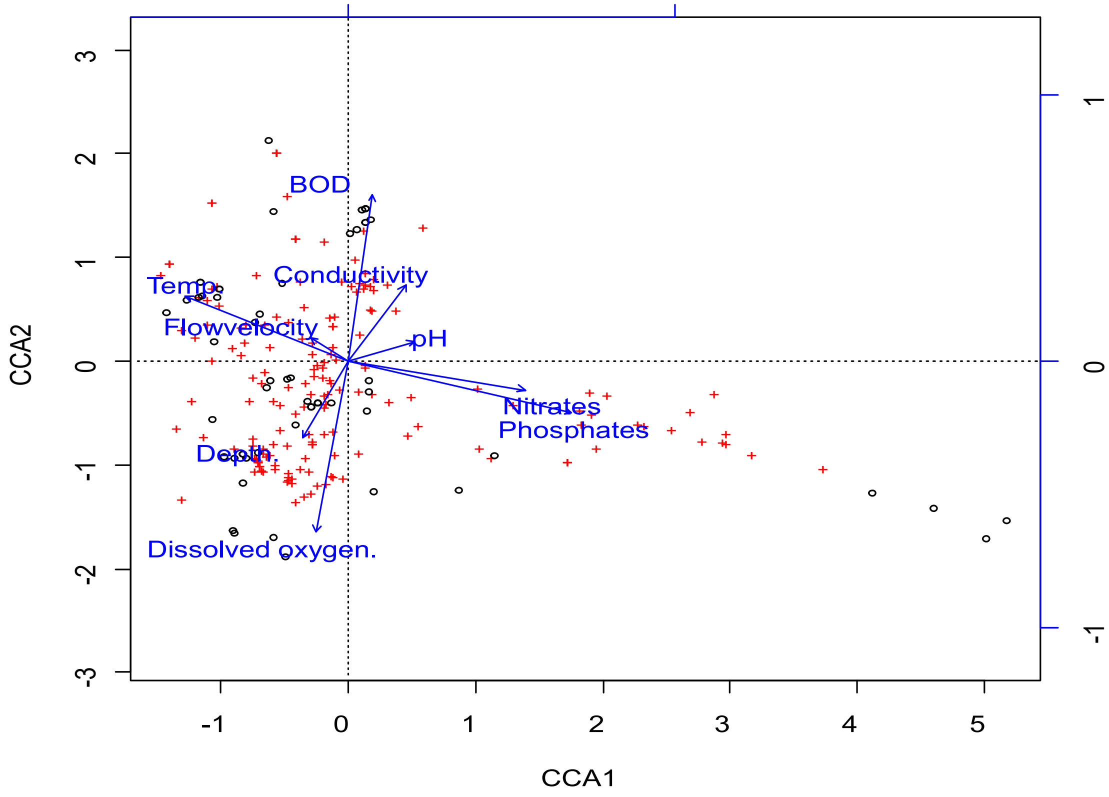

Figure 4b: CCA showing the relationships between the macroinvertebrates indicator species of the impacted stations and the environmental variables prevailing at the stations. Open circles = site scores, crosses = species scores; based on symmetric scaling.

Table 3b: Summary of Canonical (Constraint) correspondence analysis (CCA) of indicator species assemblage structure and environmental predictors correlations for impacted sites

	Axis 1	Axis 2	Axis 3
Eigen value	0.38198	0.37084	0.22347
Proportion explained (%)	29	28	16
Temperature	**0.4995**	0.24369	-0.0716
Depth	0.1405	-0.28520	**-0.6061**
Flow velocity	-0.1165	0.08752	-0.1648
Conductivity	0.1758	0.28524	-0.2447
Dissolved oxygen	-0.1002	**-0.64070**	**0.4725**
BOD	0.0753	**0.62474**	-0.1853
pH	0.2026	0.07529	-0.1193
Nitrates	**0.5413**	-0.10776	-0.3779
Phosphate	**0.6851**	-0.19440	-0.0868

All canonical axes were significant. Values in bold indicate significant difference at $p < 0.05$.

DISCUSSIONS

The main patterns produced by the clustering method and NMDS were similar - thus the presence of complex and numerous overlaps among the community types produced by ordination shift – and this clearly showed that the community types produced in the system were not discrete. This continuous characteristics of variations in the community assemblage across these streams is plausibly linked to the fact that the benthic macroinvertebrates species responded differently and independently to the environmental predictors. - since species are characterised by varying environmental habitats (Heino, 2005; Heino *et al.,* 2014). Similarly, it was not surprising to have observed clear absence of discrete community types across sites following the fact that earlier studys of heavily humanly-induced polluted streams revealed that variations in community strucuture were continuous, in spite of discrete environmental quality changes (Merovich and Petty, 2010; Heino *et al.,* 2014). Furthermore, different environmental niches of species and observed overlap among the community clusters may also have been responsible for the considerable variation in community structure across the sites. Nonetheless, it was observed that even in communities that were far more homogeneous in clustering, variations in assemblage structures among sites were evidenced. It is suggested here that variation in the size of streams among the sites comprising the particular community cluster may have been responsibe for such variations in commuity structures with more homogenous community clusters.

Indicator species (IS) are refered to as biotic organisms that are easy to monitor, and whose condition gives reflection or prediction of the status of the environment where they are seen (Bartel, 2006; Burger, 2006; Siddig *et al*., 2016). Indicator species have been considered in broad suites of studies in ecology and the environment. (Borret *et al*., 2014; Sidding *et al*., 2016). The assessment of the environmental coupled with the conservation of biodiversity have most often been based on species indicator groups (Caro, 2010). In freshwater ecology, mayflies, stoneflies and caddis flies have emerged top in the consideration of typicall sensitive indicators of ecological and environmental perturbation (Resh, 2008; Heino *et al*., 2015b). Similarly, dragonflies are already proven as being viable and reliable indicator group of the general freshwater biodiversity, especially for tropical streams (Simaika and Samways, 2011; Heino *et al*., 2015b). In congruence to this research, the indicator species found by the Indval in this study for the reference stations were all sensitive indicators and as such proposed here as ideal indicators of environmental degradation in Niger state stream.

Most of the statistically significant indicator taxa were strong indicators of the community clusters (Indicator Value > 0.5), and are also common species that occur across environmental gradients in both northern and southern Nigeria. In contrast, *Cordulia* sp., *Encentridophorus spinifer*, *Naboandelus africanus,* *Leptonema* sp., *Ranatra* sp., *Dugesia* sp. and *Crassabwa* sp were rather weak indicators of the reference community since their indicator values were slightly less than 0.5. Similarly, *Culex pipiens, Ablabesmyia* sp., and *Arrenurus damkoehlei* were weak indicators of the impacted communities have earned indicator values less than 0.5. However, these species were significant indicators of their various community clusters because there were variations among their respective clusters (they were highly specific) (Heino *et al.,* 2014). The weak indicator status showne by the other species are suggestive of the fact that species distribution along gradients of the environment is individualistics and independent, and such distributions can also be at intervals because of constant environmental disturbances that typify streams and also because subsequent extinction-colonization processes follow (Heino and Mykra 2008; Brown *et al.* 2011, Swan and Brown 2011; Heino *et al.,* 2014).

Pollution-intolerant macroinvertebrates usually die out when a river becomes contaminated. Ephemeroptera (the mayflies), Plecoptera (stoneflies), Tricoptera (caddis flies), and Decapoda (crayfish) are categorized as pollution sensitive taxa (Sharp *et al*., 2015) and their presence in a river shows a high level of water quality. In this study, Ephemenoptera, Tricoptera, and Decapoda were very abundant in the reference stations. The high population of these pollution sensitive taxa in the reference stations was suggestive of the fact that the reference stations had very low levels of pollution, and this was further supported by the results of the environmental variables of the the stations that portrayed good environmental quality.

However, Plecoptera, being among the most population sensitive taxa was not found by the indval model. It was not surprising anyway as the product of a species relative abundance and is frequency equals the indicator value of that species, and this indicator value ranges from 0 (which depicts no indication) to 100 (which depicts perfect indication) (Petersen and Keister, 2003). The characteristics of a perfect indicator should include the following: the perfect indicator belonging to a specific group should be faithful and unique, and should not occur in any other group (McCune and Grace, 2002). It was observed from this that both the relative abundance and frequency of plecoptera was very poor in all cases. The paucity of stonefly nymphs in tropical African streams has already been reported by Dobson *et al*. (2012), so the plecoptera species paucity in this study was not strange. The findings of Zabbey and Hart (2006), Arimoro *et al* (2008b, Arimoro and Keke (2017) and Keke *et al*. (2017) corroborated this claim on plecoptera paucity in tropical Nigerian streams.

The constraint ordination using CCA revealed that the macroinvertebrates species indicators for the reference stations preferred flow velocity, dissolved oxygen and conductivity - all these were mostly indicators of good water quality. It was not surprising to have all these variables picked by the ordination method since the environmental variables have earleir been posited as fundamental factors in benthic macroinvertebrates community variations of reference streams. High dissolved oxygen is associated with fast flowing waters in the headwater/reference stations and these are indicators of good environmental quality (Maagad, 2012). The association and preference of the species indicators of reference sites to dissolved oxygen and flow showed that they were really pollution sensitive since they were abundant in high oxygenated streams, with high flow velocity - and may be eliminated and replaced when the dissolved oxygen is depleted. High levels of conductivity are attributable to so many sources so the actual effects contributing to conductivity are difficult to predict since the specific ions implicated in conductivity are not individually considered when measuring conductivity.

On the other hand, the macroinvertebrates found for the impacted stations by the indval in this study were taxa that have been widely employed as surrogates for organically polluted areas in Nigeria and elsewhere (Andem *et al*. 2014; Olumukoro and Dirisu, 2014; Sharpe *et al*., 2015; Sharma and Chowdhary, 2011; Siddig *et al*., 2016). In congruence, the constraint ordination using CCA revealed that these species of the indicators of the impacted stations had affinity with and preference mostly for high BOD, dissolved oxygen, and high concentrations of nutrients (phosphates and nitrates). High BOD, phosphates and nitrates are indicators of gross pollution and organic loads and as such favored taxa such that were found by the indval for the impacted sites. These organisms are common sights in polluted environments that are rich in nutrients (nitrates and phosphates) and poor in dissolved oxygen with high BOD (Efe *et al*., 2012), and such was the case of our findings in this study. The cluster nature of indicator species of the impacted sites corroborated with the findings that communities at disturbed sites contain closely related disturbance- adapted species. (Helmus *et al*, 2010; Brunbjerg *et al*., 2012; Mykra *et al*., 2016). The lack of concordance in environmental variables-requirements of the reference species versus the impacted indicator species showed that the two taxa responded to entirely varied environmental conditions – as was evidenced by the absence of any clear environmental variables shared between the two status classes.

Freshwater conservation strategies and monitoring programs usually rely so much on benthic macroinvertebrates as species indicators of ecological integrity. Therefore, this study has provided a reference point and effective tool to monitor environmental changes, community and ecosystem dynamics in Niger state streams with the ultimate goal of preserving and conserving the stream biodiversity. However, the potential and veritable usefulness of this tool in generating very useful predictions of other aquatic biodata may be limited. It is therefore advised that components of freshwater biota be tested for possible use as surrogates in freshwater biodiversity research of these streams.

Author's Contributions

UNK: Study design, statistical analysis, proofread and financed the research publication.
UNK, FOA, AVA & IAAE : Sample collection, analysis and write-up of this work.

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