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Assessing the Ecological Health of a River in North-West Nigeria using Macroinvertebrates Structural Assemblage and Environmental Factors

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AOE conceptualizes and design the study, acquired funding for this study, collected datasets for the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors GOO, ECO, EO, LOJ, EOO and KHN managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The ecological health of River Kafin Hausa was assessed in three well marked out stations for a period of four (4) months, spanning from January to April, 2018. Water samples were collected at each sampling site and analysed according to approved standard. The habitat quality evaluation index (QHEI) was used to assess the habitat quality of the riparian zone of the river. A modified kick net with 4.4 square feet (1.36m^2) squared frame net was used to sample macroinvertebrates. Water quality variables were not significantly different among the months and stations sampled.

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Electrical conductivity, pH and TDS were higher in station 2 with mean value of 327±34µS/cm, 11 and 200.05±20.95mg/l respectively. Station 1 had the highest QHEI value of 49%. A total of 11 classes/orders, 23 families and 24 taxa of macroinvertebrates were recorded. Gastropoda was the most represented order of macroinvertebrates. Diversity indices showed significant differences (p<0.05) in the means of Taxa, Evenness and Margalef Index in station 2. The canonical correspondence analysis revealed a very weak relationship between the species composition and abundance with the selected environmental variables in the river. Flow velocity was found to influence the composition of Corbiculidae, Hydrobiidae and *Potadoma* sp. *Chironomus* sp., Viviparidae and *Gyrinus* sp. were associated with station 2. Bray-curtis similarity clearly showed no pattern of clustering between the months and stations. The study shows that the river has been subjected to disturbance in the river channels and catchments which was hinged on incessant anthropogenic activities.

Keywords: Habitat quality; EPT, flow velocity; macroinvertebrates diversity; River Kafin Hausa; Nigeria.

1. INTRODUCTION

The increasing pollution influx on freshwater ecosystems in Sub-Sahara Africa, Nigeria inclusive has called for more attention in assessing the ecological health of the systems [1,2]. Ecological health of freshwater systems is paramount to provide clean and reliable sources of freshwater to the ever increasing population occasioned by rural-urban migration in Nigeria were many of the freshwater systems catchments are rapidly urbanizing at an alarming rate.

Clean freshwater is an important natural resource for human needs [3,4]. Due to the fragile nature of the freshwater ecosystems, a great effort is needed to conserve and protect them from the present and future degradation. Therefore, water quality monitoring using macroinvertebrates and environmental factors is frequently conducted to curtail the level of degradation. The physico-chemically-based monitoring alone cannot guarantee the quality of freshwater, hence, the need for combine biomonitoring method of using both physico-chemical factors and aquatic macroinvertebrates assemblage to determine the health conditions of the systems. Aquatic macroinvertebrates are effective in biomonitoring as they occupy a very important position in the aquatic food chain, they are highly diverse and represent the local condition of the ecosystem as they are generally less mobile unlike the nektonic aquatic biota [2,5]. The assessment of aquatic ecosystems using physico-chemical factors and macroinvertebates is more effective compared to the use of only physico-chemical monitoring because it reflects the overall ecological condition (physical, chemical, and biological).

Macroinvertebrates species composition and diversity have been used in different quarters to assess the pollution status of water bodies in Nigeria [5,6]. Some groups of macroinvertebrates such as the Ephemeroptera, Plecoptera and Trichoptera (EPT) have been reported to be sensitive to pollution in water bodies. Several studies have explored and applied the EPT in biomonitoring freshwater system [e.g. 5,6,7,8,9].

In Nigeria, health of river systems are being threatened by changes in land use and other anthropogenic activities that cause harmful effects on water quality, stream habitat, and aquatic invertebrate's biodiversity depending on the type, concentration, and duration of exposure [4,10,11,12]. Most freshwater bodies have consequently been subjected to increasing number of pollutants, affecting greatly their quality and health status [11,13]. Pollutants alters the physicochemical properties of water as well as the habitat quality of the systems. Variations in these water properties greatly influence the structure and distribution of macroinvertebrate community structure in the water [12]. Hence, the use of macroinvertebrates structural-assemblage for assessing water quality will provide a clue for environmental management and quality decision making towards accurate and justifiable actions with regards to the state and quality of freshwater ecosystems [10,12]. However, despite the use of macroinvertebrate structural assemblages and environmental factors in biomonitoring freshwater systems in Nigeria, much attention has not been given to the use of habitat quality index. Habitat quality index is the use of selected indices criteria mapped out for the assessment of both the instream and riparian condition of freshwater ecosystems [14]. It is in this view the present study explored and applied a combination of selected physico-chemical variables, macroinvertebrates community structure and qualitative habitat evaluation index (QHEI) in a bid to assess the current health status of River Kafin Hausa, Jigawa State, Nigeria.

River Kafin Hausa is an ephemeral stream which serves as irrigation site for farmers within and around Kafin Hausa and Auyo Local Government Areas of Jigawa State, North west Nigeria. The river also serves as refuse dumpsite for the teeming population around the river catchment. Other anthropogenic activities around and within the river include: source of potable water supply for domestic use, defaecation point and point source site for release of waste from nearby farms. All these activities contribute to the level of deterioration the river is currently undergoing. Therefore, this study is pertinent as it will be an eye opener for the appropriate authorities to avert further deterioration in the systems and proffer ways in which the aquatic resources can be protected and conserved.

2. MATERIAL AND METHODS

2.1 The Study Area

River Kafin Hausa is an ephemeral stream which takes it source from River Wudil and flow north wards through major towns which include; Miga, Kafin Hausa, Auyo, Baturia, etc. and terminates at River Hadejia in Hadejia. The water body is a distributary of River Hadejia. It is located in the interception of Longitude 9.9131^{o}E and Latitude 12.2406^{o}N [12] of the equator. It is a municipal stream which serves as sources of potable water, irrigation sites for farming activities and other domestic activities. The area is a tropical climate with mean annual temperature of about 37.0^{o}C. The vegetative cover reflects that of Sahel savanna zone characterized by sparsely distributed artificial trees species, shrubs with little or no grassland. The area shows two distinct seasons i.e. wet and dry seasons. The wet season is between May to September and dry season between October to April [15]. Harmattan weather condition also characterized the climatic condition of this area, which is usually in the dry season months of November to February. During the season of harmattan the temperature of the area can be as low as 10.0^{o}C most especially between December and January. The study was carried out for four months between January and April, 2018. Samples were collected during the sampling period at the early hour of between 7am and 1pm monthly. Three marked out stations were selected based on community and anthropogenic activities. The three stations were; **station 1:** Magariya Community by the Bridge in Kafin Hausa, **station 2:** about 2 kilometers away from station 1 and **station 3:** Shamarama Community (about 1.5 kilometer away from station 2) in Auyo Local Government Area of Jigawa State (Fig. 1). The stations are characterized by open defaecation, cattle grazing, sheep, goat grazing, irrigation activities, sand dredging, fishing, farming, washing, bathing and other domestic activities. The stream bed is mainly mud, clay-sand, sand-loam, loam, silt and stones. The dominant vegetation in all the stations is *Azadirachta indica* (Neem plant), a domesticated plant.

2.2 Determination of the Physico-Chemical Factors

On site, during each sampling event, air and subsurface water temperatures were measured using mercury in glass thermometer. Electrical conductivity, salinity and TDS were measured using Conductivity meter DDSJ-308A and turbidity was measured using Portable Turbidity meter model WGZ-B while pH was measured using pH meter (HANNA HI 9828 multi-probe meter manufactured by HANNA instruments). Average mid-channel water velocity was measured in three replicates by timing a float as it moved over a distance of 10 m for flow velocity [16]. Water depth was measured in the sampling area using a calibrated rod recorded in meters. Transparency was measured using Secchi disc. Phosphate, nitrate, salinity, TDS and turbidity were analyzed according to [17] methods. Analysis of all samples commenced within 24 hours of sampling. Substratum composition in each 25- m sampling reach was estimated visually as percentage of silt, sand, stone and clay.

2.3 Determination of the Habitat Quality Parameter

The qualitative habitat evaluation index (QHEI) is a physical habitat index designed to provide an empirical, quantitative evaluation of the general lotic microhabitat characteristics that are important to aquatic communities [18]. The QHEI is composed of thirteen (13) principal metrics i.e. Embeddedness, Pool substrate characterization, Velocity/depth combination, Pool variability, Sediment deposition, Channel flow status, Channel alteration, Frequency of riffles (or bend), Channel sinuosity, Bank stability (condition of banks), Bank vegetative protection, Epifaunal substrate/available cover and Riparian vegetative zone width [14], with maximum possible QHEI site score of 100. Each of the metrics was scored individually and then summed to get a total QHEI site score. At each sampling station a reach of 25m was selected and habitat characterization was carried out.

2.4 Sampling of Macroinvertebrates

Macroinvertebrate samples were collected by a 3- minutes modified kick method with a 4.4 square-feet (1.36m^2) square shaped-frame net (700µm mesh) along an approximate 25 m long wadeable stretch of the river as described by [19]. Five different samples were taken at each sampling station which covered all different substrate and flow regime zones.

Samples collected were sorted before preservation. Live sorting was done in the field immediately after collection. Samples collected after sorting were preserved in 10% formalin and transported to the Department of Biological Sciences, Sule Lamido University, Kafin Hausa, Nigeria for identification and enumeration. Macroinvertebrates samples were identified and enumerated using the key and references by [20] and consultation with benthic macroinvertebrate taxonomist.

2.5 Data Analysis

The range, mean and standard error for each physical and chemical variable were calculated per station. Summary of biological metrics including abundance, number of taxa, Shannon diversity index, Evenness, Simpson dominance, Margalef's index as well as physical and chemical variables were compared between stations using two-way analysis of variance (ANOVA). Significant differences between stations indicated by ANOVA (p<0.05) were followed by Kruskal Wallis test. Taxa richness (Margalef's index), Simpson dominance diversity (Shannon index) and Evenness indices were calculated using the PAST Statistical Package [21]. Canonical correspondence analysis (CCA) was used to evaluate relationships between macroinvertebrate composition, distribution and environmental variables using PAST statistical package [21]. Prior to the final CCA, variables exhibiting high multi-colinearity (Pearson correlation r>0.80, p<0.05) were removed. Rare species, occurring less than 1 % of sampling event at each sampling station were not included in the CCA. Physical and chemical variables used for the CCA analysis were also log (x+1) transformed to prevent the undue influences of extreme values on the final CCA ordination. Species– environment correlation coefficients provided a measure of the explanation of community patterns by individual physical and chemical variables. A Monte Carlo permutation test at 999 permutation argument was used to assess the significance of the first three canonical axes. Cluster analysis based on Bray–Curtis similarity index was used to ascertain whether aquatic insects assemblage distribution were influenced either by differences in sampling stations or months. Cluster analysis was performed on log (x+1) transformed macroinvertebrate abundance data. Cluster analysis was performed using PAST statistical package [21].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Water quality of the sampled stations of river Kafin Hausa, Jigawa State, Nigeria

The mean, standard error, minimum and maximum values, ANOVA (F-values, p-values of the physicochemical variables, Kruskal Wallis test between stations means are summarized in Table 1.

The Air temperature was highest in station 2 (26.6°C) with standard error of 2.43. Monthly and station variation in air temperature showed no significant difference (p>0.05). Mean flow velocity of station 3 was 0.087±0.054m/s compared to stations 1 and 2 flow rate which was a little bit low. Electrical conductivity and pH were higher in station 2 with a value of 327±34µS/cm and 11 respectively. pH was above the limit given by FEPA, standard organization of Nigeria (SON) and world health organization (WHO). Station 2 was less turbid compared to other two stations with a value of 36.8±33.5NTU. There was no significant difference in turbidity among the months and stations sampled (p>0.05). Station 2 also had the highest TDS value of 200.05+20.95mg/l. The value recorded was far higher than the maximum limit. Nitrate and phosphate were higher in stations 2 and 3 respectively. All physicochemical variables showed no significant difference among the months and stations sampled (p>0.05) (Table 1).

3.1.2 Habitat quality of the sampled stations of river Kafin Hausa, Jigawa State, Nigeria

The features of reach of the three (3) sampled stations were unconstrained. The riparian vegetation was non-native dominated by *Azadirachta indica.* Land use was mainly for agriculture. The biotopes for the three stations were a mixture of mud and other stream bed. Canopy cover were totally absent in the three stations sampled (Table 2). The Qualitative Habitat Evaluation index (QHEI) for the three stations were 49%, 42% and 37% for stations 1, 2 and 3 respectively (Fig. 2).

3.1.3 Composition, Distribution and Abundance of the Benthic Macroinvertebrates in the River Kafin Hausa, Jigawa State, Nigeria

A total of 11 Classes/Orders, 23 families and 24 taxa of macroinvertebrates were recorded during the study period (Table 3). Station 1 accounted for the highest number of individuals (613), followed by station 2 (242) and station 3 (203). A total of 1058 individual macroinvertebrates were recorded during the study period. Gastropoda was the most represented order of aquatic macroinvertebrates with 409 Hydrobiidae individuals in station 1 and 84 individuals in station 3. This was immediately followed by *Unio* sp. (Unionidae) with 31, 41 and 51 individuals in stations 1, 2 and 3 respectively (Table 3). Among the insect orders recorded the Order Coleoptera, family *Gyrinus* sp. (Gyrinidae) was the most preponderance with 76 and 12 individuals in stations 2 and 3 respectively. *Gyrinus* sp. was not recorded in station 1. Chaoboridae (Diptera), Noteridae (Coleoptera), Baetidae (Ephemeroptera) were represented by one individual each in station 3 while Ecnomidae and Hydropsychidae (Trichoptera), Ephemerellidae (Ephemeroptera) and Atyidae (Crustacea) were also represented by one individual each in station1 (Table 3).

3.1.4 Diversity of macroinvertebrates in river Kafin Hausa, Jigawa State, Nigeria

Station 1 had the highest mean taxa (10$\pm$0.91), this was followed by station 3 (5$\pm$1.73), then station 2 (3.5$\pm$0.96). There was no significant difference between mean taxa of stations 1 and 3 (p>0.05). Station 2 showed highly significant difference among the stations diversity (Table 4). Station 1 had the highest mean abundance of 153.3$\pm$62.5 while station 2 was the lowest (51.5$\pm$19.79). Significant difference was not showed among the three stations mean abundance. No significant difference was recorded in species dominance among the stations sampled (p>0.05). Simpson Dominance for stations 1 and 3 were the same with a value of 0.47$\pm$0.139 and 0.47$\pm$0.080 respectively. There was no significant difference of Simpson Dominance mean among the stations sampled (p>0.05). Shannon-Weiner diversity (H) mean was relatively higher in station 1 (1.18$\pm$0.29). There was no significant difference in the mean of Shannon-Weiner Index among the three stations (p>0.05). Station 2 was more even in macroinvertebrates than the other two stations (Table 4); station 1 was less even in species. Menhinick and Margalef index were relatively higher in station 1 and no significant difference among the sampled stations for Menhinick index (p>0.05), but station 2 showed significant difference in station 1 (p<0.05) for Margalef index while for Menhinick index station 2 showed no significant difference while Margalef showed significant difference.

3.1.5 Macroinvertebrates and selected environmental variables association in river Kafin Hausa, Jigawa State, Nigeria

Canonical correspondence analysis showed a very weak relationship between species composition, abundance and the selected measured environmental variables in River Kafin Hausa (Fig. 3). The first three canonical axes explained about 69% of the variation in the data set collected from the study area (Table 5). Axis 1 accounted for the highest percentage variation of 29.09%, followed by axis 2 (23.21%) while axis 3 accounted for the lowest variation in the data set (16.33%). Monte Carlo Permutation at 999 permutation argument revealed that the first three canonical axes were significantly different (p<0.05) (Table 5). The Eigen values for the three CCA triplot was 1.71 with stations 1, 2 and 3 having an Eigen value of 0.72, 0.58 and 0.41 respectively. Axis 1 was slightly associated with Hydrobiidae, Corbucilidae, *Nepa* sp., Gomphidae, *Libellula* sp., *Hirudo* sp., Hygrobiidae and *Potadoma* sp. Bythinidae were lightly explained by flow velocity, phosphate, turbidity, water temperature, electrical conductivity, transparency, water depth and nitrate while axis 2 showed a very weak association with Gyrinidae, *Chironomus* sp., Viviparidae and Potamanthidae and this relationship was only explained by air temperature. *Nepa* sp. and Gomphidae were associated with water temperature, electrical conductivity and transparency. These organisms can be said to be lovers of high electrical conductivity and transparent water. They can be said to strive well in relatively clear and highly conductive water. Flow Velocity increase was found to influence the composition, abundance and distribution of Corbucilidae, Hydrobiidae and *Potadoma* sp. So, it can be inferred from this explanation that Mollusca in the river strive more in fast flowing water. Libellulidae, *Hirudo* sp., Bythinidae, Hygrobiidae, Gyrinidae, Chironomidae, Viviparidae and Potamanthidae were not linked to any environmental variable. Nutrients (nitrate and phosphate) most especially nitrate was an outlier variable as it was completely not close to any biota. *Chironomus* sp., Viviparidae, *Gyrinus* sp. were dominant in station 2 while *Hirudo* sp., Bythinidae and Hygrobiidae were shared between stations 1 and 2 in February 2018. Station 1 in March 2018 accommodated more of *Nepa* sp. and Gomphidae while *Potadoma* sp., Hydrobiidae and Corbucilidae were recorded more in April 2018 in station 1. Again *Nepa* sp. and Gomphidae were found close to the middle of the triplot.

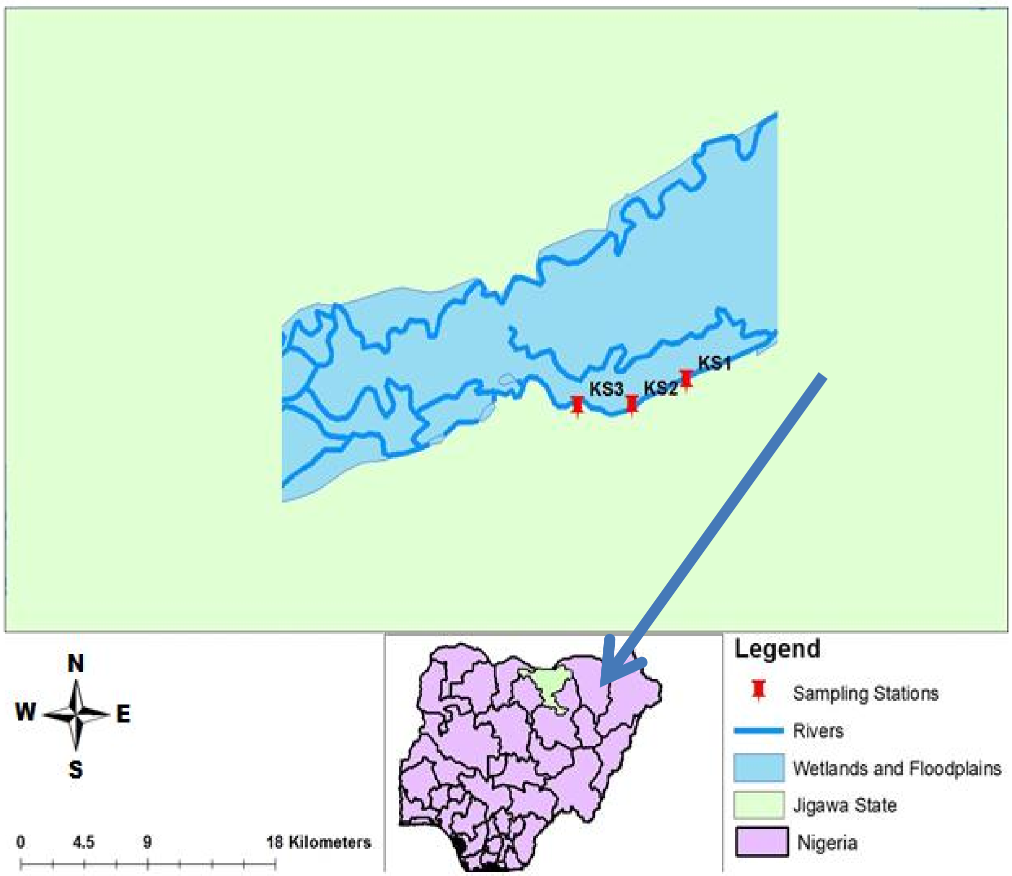

Fig. 1. Map of the study area showing the sampling stations (Map of Nigeria and Jigawa State insert)

Table 1. Summary of physico-chemical variables of the study stations of River Kafin Hausa, Jigawa State, Nigeria

Variables	Station 1	Station 2	Station 3	Months		Stations		FEPA*	SON**	WHO***
				F-value	*p*-value	F-value	*p*-value	Maximum permissible limits		
Air Temperature (°C)	25.70±2.38 (19.0–29.9)[a]	26.6±2.43 (21–32.5)[a]	26.58±3.24 (18.5–33.8)[a]	2.50	0.156	0.051	0.951	40	Ambient	
Water Temperature (°C)	19.4±1.68 (14.5–22)[a]	17.5±0.5 (17–18)[a]	20.5±1.5 (19–22)[a]	0.088	0.80	0.43	0.70	40	Ambient	
Water Depth (m)	0.35±0.082 (0.16–0.56)[a]	0.28±0.035 (0.24–0.31)[a]	0.33±0.065 (0.26–0.39)[a]	0.014	0.92	0.73	0.58	-	-	
Transparency (cm)	13.78±1.79 (10.5–18.6)[a]	15.25±2.75 (12.5–18)[a]	15.25±2.75 (12–18)[a]	14.71	0.062	0.62	0.62	-	-	
Flow velocity (ms^{-1})	0.02±0.00071 (0.02–0.023)[a]	0.028±0.005 (0.023–0.035)[a]	0.087±0.054 (0.033–0.14)[a]	1.27	0.38	1.48	0.40	-	-	
Electrical Conductivity (µScm^{-1})	316.75±33.13 (249–390)[a]	327±34 (293–361)[a]	285±12 (273–297)[a]	7.23	0.115	6.98	0.13	-	1000	600
pH	10.55 (10.1–11.2)	11 (11–11.1)	10.65 (10.5–10.8)					6.0–9.0	6.5–8.5	7.0 – 8.5
Turbidity (NTU)	153.53±22.17 (104.3–199.2)[a]	36.8±33.5 (3.3–70.3)[a]	189.3±10 (179.5–199.5)[a]	0.11	0.77	7.07	0.12	5.0	-	5.0
Total Dissolved Solids (TDS, mgl^{-1})	191.5±18.9 (152–230)[a]	200.05±20.95 (179.1–221)[a]	190.2±9.8 (180.4–200)[a]	0.50	0.55	1.86	0.35	10.0	-	5
Nitrate (mgl^{-1})	0.22±0.032 (0.149–0.304)[a]	0.27±0.13 (0.14–0.40)[a]	0.19±0.042 (0.143–0.28)[a]	11.21	0.079	0.97	0.51	-	-	600
Phosphate (mgl^{-1})	0.24±0.027 (0.171–0.301)[a]	0.21±0.0075 (0.21–0.22)[a]	0.34±0.18 (0.157–0.52)[a]	1.51	0.34	0.56	0.64	5.0	-	-

Note: Values are Mean±Standard Error; range in parenthesis. Different superscript letters in a row show significant differences (p<0.05) indicated by Kruskal Wallis Tests.
**Nigerian Water Quality Standard for Inland Surface Water. FEPA (Federal Environmental Protection Agency) (1991)*
***Nigerian Standard for Drinking Water Quality. Standards Organisation of Nigeria (SON), 2007*
**** Guidelines for drinking water quality (2nd ed.). World Health Organisation (WHO) (1993)*

Table 2. Summary of the Habitat Quality of the sampled stations of River Kafin Hausa, Jigawa State, Nigeria

Habitat features	Station 1	Station 2	Station 3
Features of the reach	Unconstrained	Unconstrained	Unconstrained
Riparian vegetation	Cultivated/Artificial/Non-Native	Cultivated/Artificial /Non-Native	Cultivated/Artificial/Non-Native
Land use	Sahel Savanna/Agriculture	Sahel Savanna/Agriculture	Sahel Savanna/Agriculture
Biotopes	Mud/clay-sand	Mud/clay-loam	Silt/stones/loam, mud
Canopy Cover (%)	0	0	0

Table 3. Composition, distribution and abundance of the macroinvertebrates in River Kafin Hausa, Jigawa State, Nigeria

Class/Order	Family	Taxon		Stations		
			Code	**1**	**2**	**3**
Bivalvia	Unionidae	*Unio* sp.	Uni	31	41	51
		Anodonta sp.	Ano	4	0	0
	Corbucilidae		Cob	12	0	0
Gastropoda	Viviparidae		Viv	14	52	14
	Hydrobiidae		Hyd	409	3	84
	Bythinidae		Byt	76	17	23
	Thiaridae		Thi	4	0	0
Hemiptera	Nepidae	*Nepa* sp.	Nep	27	0	0
Odonata	Gomphidae		Gom	7	0	0
	Libellulidae		Lib	6	3	6
Diptera	Chironomidae	*Chironomus* sp.	Chi	10	24	2
	Chaoboridae		Cha	0	0	1
Coleoptera	Gyrinidae	*Gyrinus* sp.	Gyn	0	76	12
	Noteridae		Not	0	0	1
	Hygrobiidae		Hyg	2	19	3
Ephemeroptera	Potamanthidae		Poa	0	0	3
	Baetidae		Bae	0	0	1
	Coenagrionidae		Coe	0	0	1
	Ephemerellidae		Eph	1	0	0
Trichoptera	Ecnomidae		Ecn	1	0	0
	Leptoceridae		Lep	4	0	0
	Hydropsychidae		Hyp	1	0	0
						0
Decapoda/Crustacea	Atyidae	*Caridina* sp.	Car	1	0	0
Annelida	Hirudinidae	*Hirudo* sp.	Hir	3	7	1
Absolute Abundance				**613**	**242**	**203**

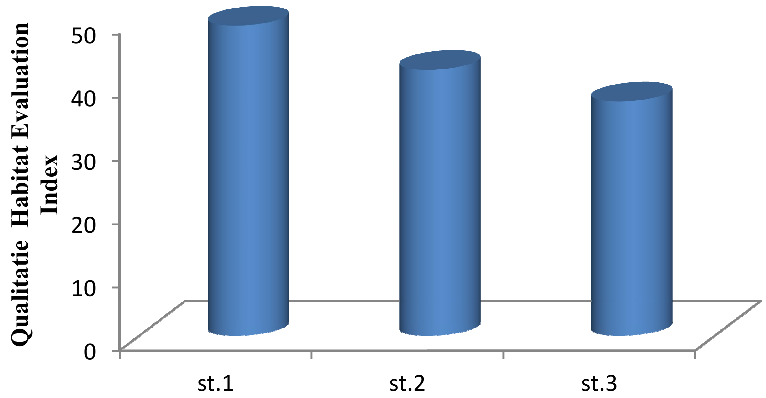

Fig. 2. Qualitative habitat evaluation index (QHEI) (%) of the sampled stations of River Kafin Hausa, Jigawa State, Nigeria

Table 4. Monthly mean number of species (taxa), Abundance, Dominance, Simpson Dominance, Shannon Weiner Diversity, Evenness, Menhinick, Margalef's and Berger-parker of benthic macroinvertebrates in River Kafin Hausa, Jigawa State, Nigeria.Value ± standard error

Indices	Station 1	Station 2	Station 3
Taxa (Species No.)	10 ± 0.91^{a}	$3.5+0.96^{b*}$	$5+1.73^{a}$
Abundance (no. of individuals)	$153.3 \pm 62.45^{a**}$	$60.5 \pm 28.23^{a**}$	$51.5 \pm 19.79^{a**}$
Dominance (D)	$0.51 \pm 0.122^{a**}$	0.46 ± 0.096^{a}	0.54 ± 0.081^{a}
Simpson dominance (D)	0.47 ± 0.139^{a}	$0.54 \pm 0.096^{a**}$	0.47 ± 0.080^{a}
Shannon Weiner index (H)	1.18 ± 0.29^{a}	0.96 ± 0.24^{a}	0.88 ± 0.21^{a}
Evenness (E)	0.38 ± 0.12^{a}	0.84 ± 0.048^{b}	0.66 ± 0.15^{a}
Menhinick index	1.96 ± 0.18^{a}	$0.50 \pm 0.11^{a**}$	0.69 ± 0.16^{a}
Margalef index (taxa richness) (d)	1.92 ± 0.18^{a}	$0.63 \pm 0.22^{b*}$	0.98 ± -0.37^{a}
Berger-parker dominance	0.66 ± 0.11^{a}	0.58 ± 0.10^{a}	0.66 ± 0.084^{a}

Note: Different superscript letters in a row show significant differences (p<0.05) indicated by Kruskal-Wallis test
** = ANOVA calculated showed highly significant difference among sampling stations*
*** = ANOVA calculated showed highly no significant difference among sampling stations*

Table 5. Weighted intraset correlations of environmental variables with the first three axes of canonical correspondence analysis (CCA) in River Kafin Hausa, Jigawa State, Nigeria

Variables	Axis 1	Axis 2	Axis 3
Eigen values	0.72	0.58	0.41
% variation of species data explained	29.09	23.21	16.33
Monte Carlo test p-value	0.018	0.001	0.02
Air temperature (^{o}C)	-0.097	0.05	-0.00056
Water temperature (^{o}C)	0.44	0.40	-0.012
Water depth (m)	0.45	0.25	-0.14
Transparency (cm)	0.40	0.34	-0.044
Flow velocity (ms^{-1})	0.053	0.62	-0.30
Electrical Conductivity (μScm^{-1})	0.44	0.38	0.01
Turbidity (NTU)	0.28	0.55	0.028
Salinity (%)	0.41	0.59	0.028
Total Dissolved Solids (TDS) (mgl^{-1})	0.44	0.39	0.0092
pH	0.43	0.37	0.0081
Nitrate (mgl^{-1})	0.745	0.15	0.0096
Phosphate (mgl^{-1})	0.26	0.63	0.014

Significance of the axes by the Monte Carlo permutation test is given by F= 2.492 (p<0.05). All canonical axes were significant (p = 0.005) for the three axes, (p<0.05)

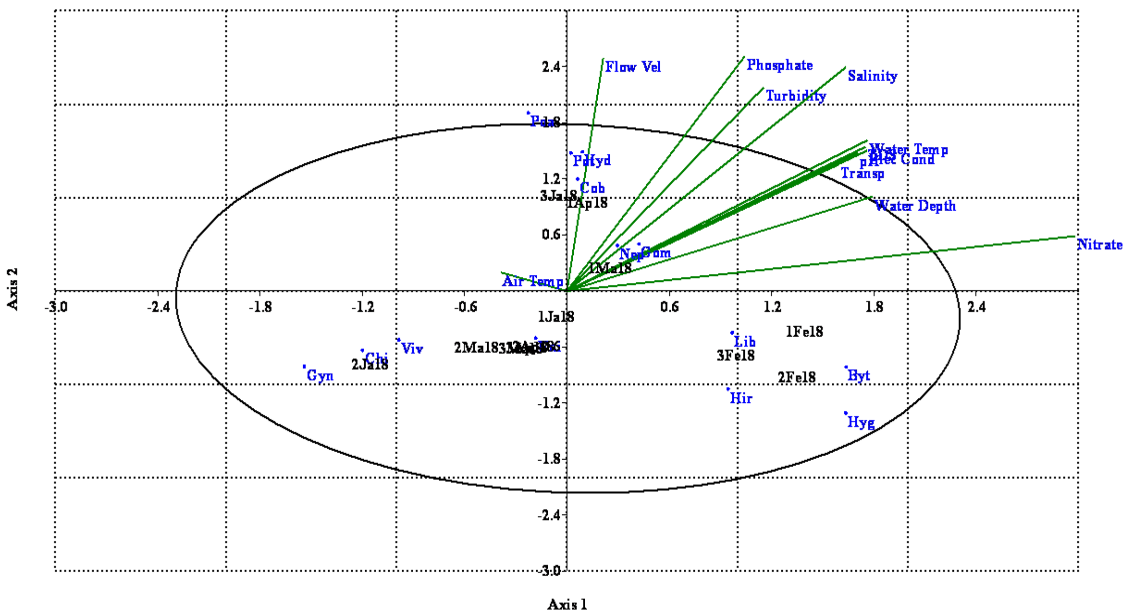

Fig. 3. Triplot of the first and second CCA axes of macroinvertebrate taxa, environmental variables and the sampling stations of River Kafin Hausa, Jigawa State, Nigeria

Macroinvertebrate abbreviation: Uni (Unio sp.), Cob (Corbucilidae), Viv (Viviparidae), Byt (Bythinidae), Pot (Potadoma sp.), Hyd (Hydrobiidae), Nep (Nepa sp.), Lib (Libellula sp), Gom (Gomphidae), Hir (Hirudo sp.), Chi (Chironomus sp.), Gyn (Gyrinus sp.), Hyg (Hygrobiidae) and Poa (Potamanthidae)(Ja January, Fe February, Ma March, Ap April and numbers 1, 2 and 3 represent the sampling stations)

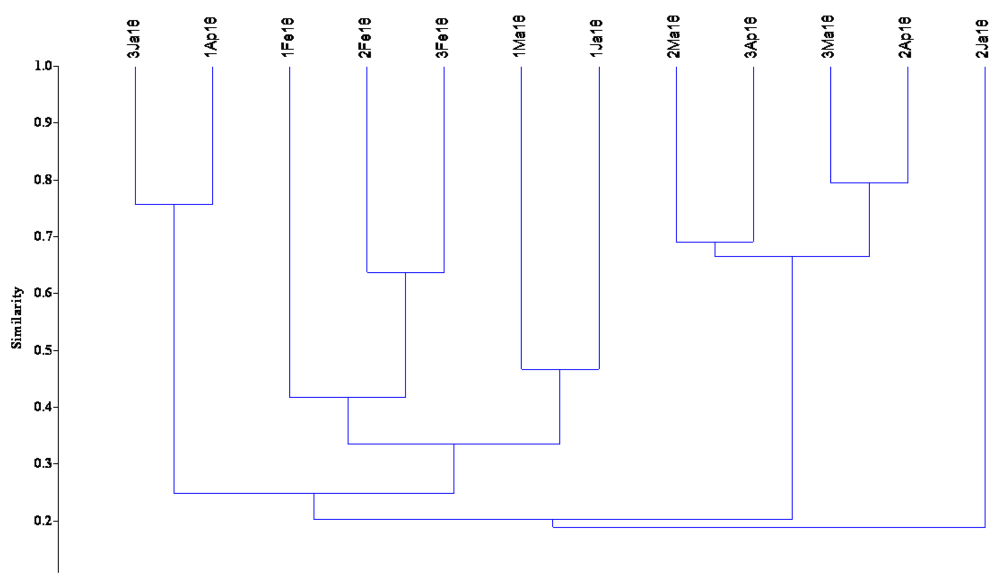

Fig. 4. Dendrogram derived from the cluster analysis (Bray–Curtis similarity index) of log (x+1) transformed macroinvertebrate abundance data in the River Kafin Hausa, Jigawa State, Nigeria during the study periods (January, 2018 – April, 2018). Ja January, Fe February, Ma March and Ap April. 18 attached to months represent the year sampling was done, 2018. Numbers 1, 2 and 3 attached to the months represent the sampling stations

3.1.6 Differences and similarities between the sampling stations based on macroinvertebrates species compositions during the study period in river Kafin Hausa, Jigawa State, Nigeria

Cluster analysis produced based on macroinvertebrates (logx+1) transformed abundance data using Bray-Curtis Similarity clearly showed that macroinvertebrates samples were neither clustered by stations nor by months. There was no definite pattern of clustering in the study area (Fig. 4). The highest similarity value was the cluster between station 1 (April 2018) and station 3 (January 2018); station 3 (March 2018) and station 2 (April 2018) with a similarity value of about 0.75. These were immediately followed by the similarity of about 0.68 in the cluster of station 2 (March 2018) and station 3 (April 2018). The third cluster was in stations 2 and 3 (February 2018) with similarity value of about 0.62, while the least cluster of about 0.48 was present in station 1 (March 2018 and January 2018).

4. DISCUSSION

4.1 Water quality (physicochemical variables) of River Kafin Hausa, Jigawa State, Nigeria

Physico-chemical variables in the present study are as seen in the tropics [6,9,22]. Elsewhere in Kenya, [23] reported a very much closer similar mean water temperature range of 16.8 – 19.1^{o}C in six rivers in Mount Kenya. This can be said to be a coincidence in climatic condition of northern Nigeria as at the time of this study and probably a winter season in Kenya where this low temperature was recorded.

Flow velocity was significantly higher in station 3. This may be due to the meandering nature of this station. Also station 3 width was significantly lower than that of the other stations. The mean flow velocity ranges between 0.02 – 0.14m/s. This is in agreement with reports by [24] in a River in Niger Delta area of Nigeria. Conversely, [9,22] reported a relatively lower flow velocities in their study conducted at Rivers Atakpo, Owan in Southern Nigeria. The relative low flow velocity in the study is may be due to the fact that these rivers flow across lowland.

The conductivity value in this study was relatively high. This is consonant with earlier report by [25]. The alkaline pH of this water may be attributed to the absent of riparian vegetation which has been reported to contribute to acidic pH in water bodies [9]. Also, the muddy constituents in all the stations cannot be totally neglected as a factor that may increase the pH of the water. It has earlier been reported by [26] that high value of pH may result due to waste discharge, microbial decomposition of organic matter in water bodies. This microbiological processes may not be absent in the reaches of this station as varied degree of anthropogenic activities are presence here which may had aggravate the pH value.

Turbidity values for all the stations sampled in this study were very high. Similar investigation by [27] reported high turbidity value which they attributed to high inflow of debris into the water body. This is not unconnected to the situation in this study area, as a Sahel savanna zone is supposedly to experience high inflow of debris as a result of erosion probably due to unavailability of riparian vegetation in the studied stations.

The disproportionately high values of TDS in this study may not be unconnected to the open nature of the riparian zones of the river which may increase the inflow of all sorts of debris into the river.

Increased nitrate concentration favours algal growth, thus resulting in eutrophication in water [28] as it was noticed in the present study.

4.2 Habitat Quality of River Kafin Hausa, Jigawa State, Nigeria

Habitat characterization carried out in River Kafin Hausa revealed that the features of the reaches were unconstrained in the three stations sampled. [29] had earlier reported a contrary view in features of reach of most of the stations sampled in Adofi River, Niger Delta area of Nigeria were constrained except one of the stations. This can be linked to the forested nature of the rivers in the Southern part of Nigeria unlike the savannah belt found in Northern Nigeria.

No riparian vegetation in this study area, except for very far away vegetation of *Azadirachta indica,* in distance of about 100 m away from the bank of the river. This is not too good for the functionality of the water bodies, as riparian vegetation are source of autochthonous (external source of food) in a given water body. Native species of vegetation are not found this study area probably due to the unfavourable environmental condition which will permit the excessive growth of plants in a given environment. Also stations 1, 2 and 3 riparian communities are not that far away from the reaches of the stations but there are farmlands in the riparian zone of the studied stations. Contrarily [9 and 29] reported a mainly native vegetation type in some forested rivers in the Southern part of Nigeria [30].

Qualitative habitat evaluation index (QHEI) from this present study showed that stations 1 to 3 were moderately impaired owing to the fact that QHEI values calculated for all the study in River Kafin Hausa were less than 79%. According to [14], QHEI score less than 21% showed that a habitat is severely impaired while QHEI score between 29% and 79% are moderately impaired while QHEI mean score of above 79% are not impaired. The level of impairment of a river increases as the QHEI mean value decreases. From, this it can be seen that station 1 with a QHEI mean score of 49% is relatively less impaired when compared to the other stations. Station 3 with QHEI value of 37% was the worst hit, probably occasioned by the degree of human activities.

4.4 Composition and Abundance of Macroinvertebrates in the River Kafin Hausa, Jigawa State, Nigeria

The relatively low composition, distribution and abundance of macroinvertebrates recorded in this study could be attributed to the various degree of anthropogenic activities going on in the reaches of the river most especially in stations 1 and 3 were high abundance of Mollusca (Bivalvia and Gastropoda) was recorded. Stations 1 and 2 had fair distribution of *Chironomus* sp., a pollution tolerant species. The presence of Gastropoda and Chiornomidae portrays organically impacted water bodies and they have been recorded in some polluted water bodies in Nigeria [5,9].

The preponderance of Mollusca in the present study can be attributed to their ability to thrive more in organically polluted river course, and reaches with high temperature. All these conditions are present in this study area. Total alkalinity has also been reported to correlate positively with Mollusca abundance [31]. In this present study pH values were reported to be slightly alkaline and this can also be a contributing factor to the preponderance of Mollusca in stations of the study area.

Hemiptera was represented by 1 taxon; *Nepa* sp., and this was only recorded in station 1 with 27 individuals. Its absence from stations 2 and 3 maybe implicated on the presence of some environmental conditions which may not favour their striving rate. [6] has earlier reported the tolerance of *Nepa* sp. to a deteriorating water condition, despite the much earlier assertion that the Hemiptera are sensitive to deteriorating water health condition [32,33].

Some species of dipteran most especially the Chironomidae have been reported to inhabit an organically polluted water bodies. This tolerant characteristics have been implicated on the adaptive mechanisms developed by this group of macroinvertebrates e.g. the possession of pigment haemoglobin which gives them a high affinity for oxygen, hence their tolerance to low dissolved oxygen concentration [5,9,34].

Station 2 harbours more of *Gyrinus* sp., which can be asserted to be a reflection of less pollution in this station. This can be attributed to the less impact of human activities unlike stations 1 and 3. Related studies conducted in similar freshwater bodies in Nigeria [9,27] and elsewhere [35] had associated the presence of these organisms in a site to clean condition. These species are very sensitive to reductions in dissolved oxygen levels. Though, it cannot be totally declared that station 2 is free of pollution, owing to the presence of some pollution tolerant species like Chironomidae.

The order Ephemeroptera includes species that are tolerant as well as those that are intolerant to various forms of pollution [36]. The Ephemeroptera has also been reported to thrive well in riffle microhabitat i.e. reaches with high flow velocity [33]. Also, some species exhibit flight mechanism as an adaptation to move from impacted water to cleaner water [37]. The Baetidae family has been discovered to fly 1.6km to 1.9km upstream of their emergence sites occasioned by pollution effect. [37] noted the upstream flight of aquatic insects most especially the Ephemeroptera as implications for stream management because of anthropogenic disturbances that adversely impact aquatic communities adjacent and downstream of their occurrence. This can be seen from the sparse distribution of the Ephemeropteran in this present study area.

4.5 Diversity of Macroinvertebrates in the River Kafin Hausa, Jigawa State, Nigeria

These values of mean monthly number of species (taxa) were relatively low when compared to higher values recorded by [5,9] in some selected water bodies in southern Nigeria. This relatively low species number recorded in River Kafin Hausa may be an indication of the perturbed state of some reaches of the river.

Mean abundance i.e. number of macroinvertebrate individuals were relatively high compared to those recorded by [5]. The increased number of macroinvertebrate individuals may not be unconnected to the preponderance of a particular species which can survive a given water with varied environmental variable differentiation. The increased mean abundance of macroinvertebrate species in station 1 may be as a result of the high preponderance of Hydrobiidae in the station, hence outweighing the number of individuals of macroinvertebrates in the other sampled stations.

Simpson's dominance (D), measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species) accounts for both abundance and evenness of the species present [37]. From this study, Simpson dominance revealed that station 2 with dominance value of 0.54 was less diverse in macroinvertebrates. This result does not conform to reports by [38] in Borkena River, Ethiopia who reported a Simpson's dominance (D) value of 0.117 – 0.465, showing more infinite diversity. This variance may be due to the geographical location of the rivers in comparison.

With special reference to Margalef's water quality index, values greater than 3 indicate clean water condition [39]. So, from this it can be concluded that all stations sampled in River Kafin Hausa are stressed [40-46].

Generally, from the diversity indices of macroinvertebrates calculated for River Kafin Hausa shows that the river is highly perturbed in some reaches of the river, occasioned by high degree of human influences.

4.6 Macroinvertebrates and Selected Physico-chemical Factors Association in River Kafin Hausa, Jigawa State, Nigeria

The environmental variables measured did not showed weak association with the biota as revealed by the CCA triplot. Flow velocity increase was found to influence the composition, abundance and distribution of Corbucilidae, Hydrobiidae and *Potadoma* sp. So, it can be inferred from this explanation that Mollucsa in the river strive more in fast flowing water. Libellulidae, *Hirudo* sp., Bythinidae, Hygrobiidae, Gyrinidae, Chironomidae, Viviparidae and Potamanthidae were not linked to any environmental variable. This can be a pointer to the fact that these organisms influenced by flow velocity have a special mechanism that enable them move with fast flowing water.

Generally, based on the CCA triplot ordination performed for the macroinvertebrates distribution and relationship with some selected environmental variables in River Kafin Hausa, it can be concluded that the organisms were not distributed based on the status of the different stations sampled. From this we made bold to say that the structural assemblage of macroinvertebrates in River Kafin Hausa were not determined by the environmental variables selected for the CCA triplot.

5. CONCLUSION

River Kafin Hausa from this study shows that it has been subjected to disturbance in the river channels and catchments; this probably may be occasioned by the incessant anthropogenic activities in the river. The diversity, abundance, distribution and composition were not too encouraging of a healthy ecosystem. However, a more robust study is required to better understand the health of riverine systems in the North West region of Nigeria. This can be achieved by assessing more riverine systems in the region. Further, other aquatic biota should be explored in assessing the health of river ecosystems.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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