



## Water Quality and Macroinvertebrates Assessment of Hadejia–Nguru Wetlands in Jigawa and Yobe States, Nigeria.

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**Abstract:** Arithmetic water quality index and Macroinvertebrates' family biotic index of Hadejia–Nguru wetlands in Jigawa and Yobe states of Nigeria were determined. Four sampling locations labeled L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub> and L<sub>4</sub> and a control location labeled L<sub>C</sub> were chosen. Water samples were collected using plastic containers that were washed with water and detergent, soaked in 10% HNO<sub>3</sub> while Macroinvertebrates were collected using a Van Veen grab sampler. Temperature, pH, DO and Electrical conductivity were measured in-situ using a Seabird Scientific Hydrocycle (DS5X) portable meter while total suspended solids, total dissolved solids, BOD<sub>5</sub>, Sulphate, Nitrates, Ca and Mg were determined using standard methods. Macroinvertebrates were identified to the lowest possible taxonomic level using identification keys. Analysis of variance was used to compute the differences in physicochemical parameters and macroinvertebrates' values among sampling locations. The results obtained for physicochemical parameters showed highest and lowest pH as 6.63±0.41 and 5.08 ± 0.76 in L<sub>C</sub> and L<sub>1</sub> respectively, DO levels were lowest (4.50 ± 0.51 mg/l) in L<sub>1</sub> and highest (5.28±0.37 mg/l) in L<sub>C</sub> while highest and lowest BOD levels were 7.64 ± 1.67 mg/l and 5.85±1.59 in L<sub>4</sub> and L<sub>C</sub> respectively. The physicochemical parameters generally exceeded the WHO limits with control location having lower measurements though there was no significant difference (P>0.05). A total of 329 individual macroinvertebrates were identified in all the sampling locations belonging to three phyla, five classes, 10 orders and 13 families with different pollution tolerance levels. The weighted Arithmetic water quality index showed an order: L<sub>1</sub>>L<sub>2</sub>>L<sub>3</sub>>L<sub>4</sub>>L<sub>C</sub> with the highest and lowest being 6507.15 and 936.96 respectively while the macroinvertebrates' family biotic index followed same pattern with the highest (5.56) in L<sub>1</sub> and lowest (4.49) in L<sub>C</sub> indicating high degree of organic contamination making the water unfit for human use.

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### 1. Introduction

According to the Ramsar Convention, wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. A text of the convention defined wetlands as areas of marsh, fern, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters (Ramsar, 1994, Ruto *et al.*, 2012). Wetlands constitute about seven to nine million km<sup>2</sup> which is 4 to 6% of the total land surface of the world (Venessa *et al.*, 2017). They supply many irreplaceable ecosystem services, including storage and sequestration of carbon, water purification, the buffering of runoff and river discharge, the production of food and fiber, ecotourism and their total productivity in fish, wildlife, grazing and agriculture is considerably high (Gopal, 2013) as a result of which they have been historically occupied and intensively used by humans over a long period of time. Wetlands also provide habitats for some water

dependent species of organisms such as crayfish, crabs, shrimps, amphibians, reptiles, mammals and some birds that use these wetlands for nesting, breeding and rearing of young ones (Robert, 2016) especially the Palearctic migratory birds.

Nigeria is uniquely bestowed with wetlands of both freshwater and coastal saline waters, some of which are enlisted among the Ramsar sites (Olalekan *et al.*, 2014) of which Hadejia–Nguru wetlands is one. It is an extensive area of floodplain located in the north-eastern sudano-sahelian zone of Nigeria, covering an area of approximately 3,500 square kilometres. It is situated where Rivers Hadejia and Jama'are flow before converging and draining into Lake Chad. Hadejia–Nguru wetlands harbour large numbers of diverse species of wildlife, particularly Palearctic and Afrotropical migrant water birds and provide important ecosystem services which include direct use services such as farming, collection of materials such as potash, doum palm (*Hyphaene thebaica*) and fuelwood, water collection, fishing and hunting of water birds amongst others.

Degradation and loss of wetlands worldwide

are on the rise due to pollution, biological resources use, natural system modification, introduction of invasive species, agriculture and aquaculture, extraction activities, and other actions affecting the water quality and quantity (Ting *et al.*, 2019). Nick (2014) reported that long-term loss of natural wetlands averages between 54–57% since 1900 AD while pollutants in form of pesticides, metals, sewage, fertilizers, petroleum products and many other forms do contaminate the remaining available wetlands continually. Hadejia-Nguru wetlands are not exempted from the degradation and shrinking as a result of human activities, Ezekiel (2011) reported 32.88% change from wetlands in 1972 to other land-use types in 2005 in the area while several cases of pollutants occurrence such as pesticides and metals, invasive species and biodiversity loss were reported (Oduntan *et al.*, 2010; Sabo *et al.*, 2016; Ringim *et al.*, 2015).

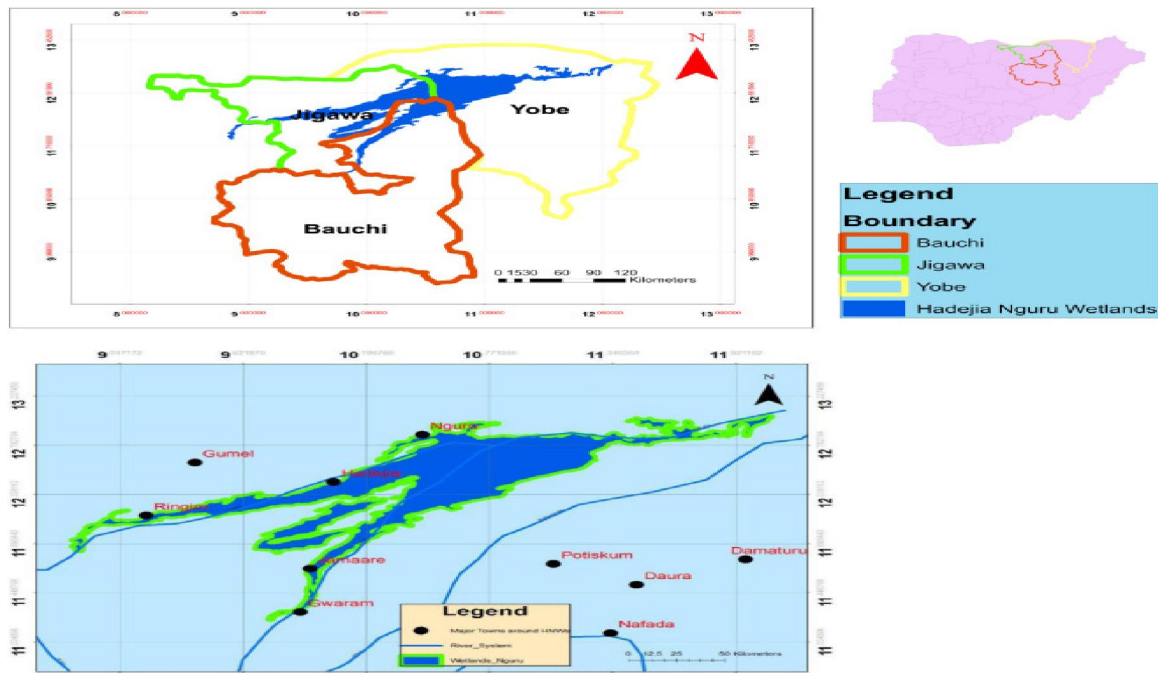
Water quality index (WQI) provides a single value that is mathematically computed taking into account the most important physical and chemical parameters, showing the overall quality of water at a specific location and time (Douglas *et al.*, 2015). Macroinvertebrates live for a long time in an area and some of them are sessile so they give a better

representation of the environmental conditions while use of biotic index as a method of measuring the overall health status of aquatic bodies through the use of macro-invertebrates remains the most reliable and effective method (Bate and Sam-Uket, 2019).

## 2. Materials and Methods

### 2.1 The Study Area

Hadejia Nguru wetlands lie between longitude 10°15'E and 11°30'E, and latitude 12°13'N and 12°55'N. The wetlands extend approximately 120 km from West to East within Jigawa State and for a further 60–70 km downstream in adjacent Yobe State. In width, the wetlands range from 10 km to more than 50 km from North to South, with approximately 8000 km<sup>2</sup> of floodplain touching three Nigerian states (namely Bauchi, Jigawa and Yobe) (Ayeni *et al.*, 2019). Four sampling locations with an average distance of 9.8 km from one another were chosen within the wetlands: Matara uku, Gadar goruba, Tukuikuyi, and Makintari which were labeled L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub> and L<sub>4</sub> respectively while another location (Jahun) about 67 km away from the wetlands was chosen as a control and labeled L<sub>C</sub>. A map of Hadejia-Nguru wetlands is presented in figure one below.



**Fig. 1: Map of Hadejia Nguru Wetlands Showing Sampling Locations**

### 2.2 Sample Collection

Samples of water and macroinvertebrates from each of the locations and the control were collected monthly for a period of six months. Water samples were collected using plastic containers that were washed with water and detergent, soaked in 10%

HNO<sub>3</sub> and rinsed with deionised water (Wyasu, 2020). Sample bottles were rinsed with sampled water three times and then filled to the brim at a depth of one meter below the surface. Macroinvertebrates were collected using a Van Veen grab where 3 or 4 hauls were made by sending the

grab down into the bottom of the river at random locations. The sediment collected was poured into a labeled white plastic can and taken to the laboratory where it was passed through three sieves of 2 mm, 1 mm and 0.5 mm mesh sizes to collect the benthos that were stained with Rose Bengal solution to highlight their hidden features and sorted using forceps. Manual collection was employed in the case of stony substrates, cobbles, boulders, leaves and submerged branches in the wetlands. The macroinvertebrates were preserved in 96% ethanol and transported to the laboratory for identification.

### 2.3 Analysis of Samples

Physicochemical parameters such as temperature, pH, dissolved oxygen (DO) and Electrical conductivity (EC) were measured in-situ using a Seabird Scientific Hydrocycle (DS5X) portable meter with multi-parameter probe while total suspended solids (TSS) and total dissolved solids (TDS) were measured in the laboratory using gravimetric analysis and TDS meter respectively and BOD<sub>5</sub> was calculated from DO values after five days incubation at 20°C as reading of the first day DO subtracted from the fifth day DO. Sulphate and Nitrates were measured by turbidimetric and Spectrophotometric methods respectively using Spectrophotometer (Prove 601), Chloride was determined by Mohr's titration according to Emre *et al.* (2019) while Ca and Mg were determined using EDTA titration.

Macroinvertebrates were identified to the lowest possible taxonomic level using the identification keys of Merritt and Cummins (1996) and McCafferty (1998).

### 2.4 Statistical Analysis

Analysis of variance (ANOVA) was used to compute the differences in physicochemical parameters and macroinvertebrates' values among sampling locations within Hadejia-Nguru wetlands and the control location.

### 2.5 Water Quality Index

Weighted arithmetic index method was used to compute the water quality index as expressed in equation one according to Shah and Joshi (2017).

$$WQI = \frac{\sum_{i=1}^n QiWi}{\sum_{i=1}^n Wi} \quad 1.$$

Where  $n$  is the number of parameters,  $Wi$  is the relative weight of the  $i$ th parameter and  $Qi$  is 0–100 water quality rating of the  $i$ th parameter.

An inverse relationship exists between the unit weight ( $wi$ ) of various water quality parameters and the recommended standards ( $Si$ ) as shown in equation two (Mehra *et al.*, 2017) while the value of  $qi$  is calculated using the formula in equation three:

$$Wi = 1/Si \quad 2.$$

$$Qi = 100 \left[ \frac{Vi - Vid}{Si - Vid} \right] \quad 3.$$

Where  $Vi$  is the observed value of the  $i$ th parameter,

$Si$  is the standard permissible value of the  $i$ th parameter and  $Vid$  is the ideal value of the  $i$ th parameter in pure water. All parameters' ideal values ( $Vid$ ) are taken as zero in drinking water except pH and DO that are taken as 7.0 and 14.6 mg/l respectively (Odibo *et al.*, 2014).

The calculated water quality indices were compared with the Weighted Arithmetic water quality scale shown in Table 1.

**Table 1: Weighted Arithmetic Water Quality Classification**

WQI	Status
>100	Unsuitable for drinking
76 – 100	Very poor
51 – 75	Poor
26 – 50	Good
0 – 25	Excellent

### 2.6 Biotic Index

Family Biotic Index (FBI) was calculated using the Hilsenhoff (1987) formula in which macroinvertebrates' taxa are assigned a tolerance index from 0–10 based on their ability to live under a variety of stressful conditions. The tolerance index is multiplied by the number of individuals in each taxon, the product is summed and divided by the total number of specimens in all groups.

$$FBI = \frac{\sum_{i=1}^S niti}{\sum_{i=1}^S ni} \quad 4.$$

where  $n_i$  and  $t_i$  are the number of individuals and the tolerance index respectively, of the  $i$ th family and  $S$  = the number of families included in the analysis. Table two shows the macroinvertebrates' family biotic index (FBI) water quality scale.

## 3. Results

### 3.1 Physicochemical Parameters of Water from Hadejia-Nguru Wetlands and the Control

There was no significant difference among physicochemical parameters of water from all the sampling locations in Hadejia-Nguru wetlands except for pH, Total Dissolved Solids (TDS) and Calcium. The highest and lowest mean pH during the study were  $6.63 \pm 0.41$  and  $5.08 \pm 0.76$  in  $L_C$  and  $L_1$  respectively. Mean dissolved oxygen (DO) levels were lowest ( $4.50 \pm 0.51$  mg/l) in  $L_1$  and highest ( $5.28 \pm 0.37$  mg/l) in  $L_C$  while highest and lowest Biological Oxygen Demand (BOD) levels were  $7.64 \pm 1.67$  mg/l and  $5.85 \pm 1.59$  in  $L_4$  and  $L_C$  respectively. The physicochemical parameters have generally exceeded the World Health Organization (WHO) limits with control location having lower measurements. Table three (3) shows the mean physicochemical parameters of water from the study area, the test of difference and comparison against WHO standards.

### 3.2 Macroinvertebrates Abundance, Composition and Distribution within the Study Area

An average number of 329 individual macroinvertebrates were identified in all the sampling locations belonging to three phyla, five classes, 10 orders and 13 families with different pollution tolerance levels. Table four (4) shows the composition and average number of macroinvertebrates with their Hilsenhoff's pollution tolerance levels.

### 3.3 Water Quality and Macroinvertebrates' Biotic Indices of the Study Area

The weighted Arithmetic water quality index (WQI) was highest (6507.15) in L<sub>1</sub> and lowest (936.96) in L<sub>C</sub> while the macroinvertebrates' family biotic index (FBI) was highest (5.56) in L<sub>1</sub> and lowest (4.49) in L<sub>C</sub>. Figure 2 shows the water quality and macroinvertebrates' family biotic indices of Hadejia-Nguru wetlands during the study.

**Table 2: Family Biotic Index Water Quality Scale the Study.**

Family Biotic Index	Water Quality
0.00–3.75	Excellent
3.76–4.25	Very good
4.26–5.00	Good
5.01–5.75	Fair
5.76–6.50	Fairly poor
6.51–7.25	Poor
7.26–10.00	Very poor

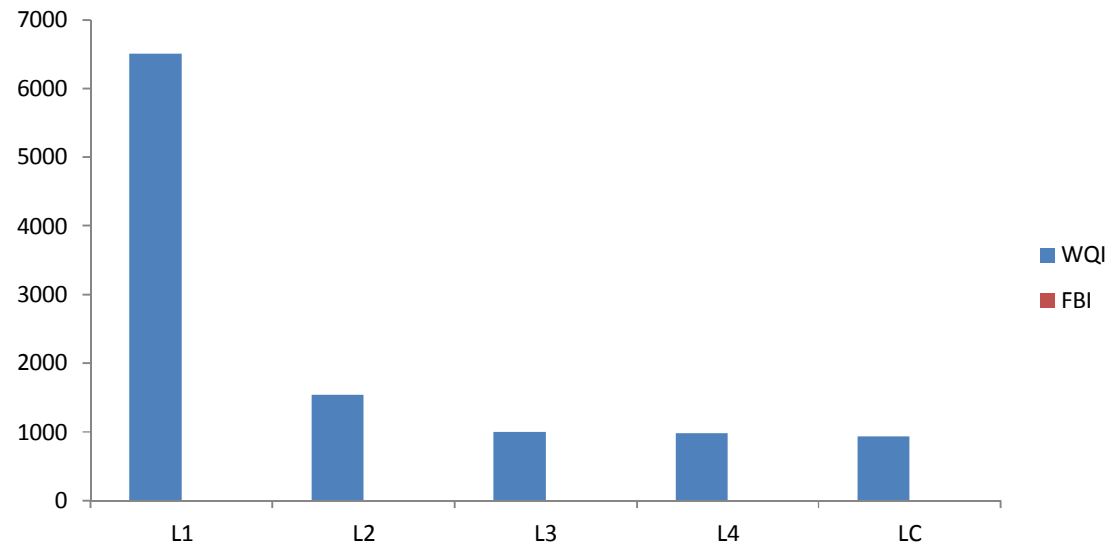
**Table 3: Mean Physico-chemical Parameters of Water from Hadejia–Nguru Wetlands and the Control, their ANOVA Test and Comparison with WHO standards**

Parameters	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>C</sub>	P-test	WHO limit
pH	5.08 ± 0.76	5.92 ± 0.42	5.93 ± 0.86	5.55 ± 0.93	6.63±0.41	P = 0.01 <sup>S</sup>	6.50 – 8.50
DO (mg/l)	4.50 ± 0.51	4.64 ± 0.76	4.62 ± 0.75	4.72 ± 0.78	5.28±0.37	P = 0.20 <sup>NS</sup>	5.0
BOD (mg/l)	6.97 ± 1.46	7.15 ± 1.45	6.95 ± 1.47	7.64 ± 1.67	5.85±1.59	P = 0.40 <sup>NS</sup>	5.0
TDS (mg/l)	580.83 ± 86.18	627.33 ± 76.72	607.50 ± 95.78	589.17 ± 98.47	473.0±66.54	P = 0.03 <sup>S</sup>	500
EC (µS/cm)	273.50 ± 63.25	271.83 ± 29.89	250.83 ± 39.37	270.50± 69.17	251.56±67.2	P = 0.09 <sup>NS</sup>	250
Turbidity (NTU)	6.70 ± 1.34	6.82 ± 1.43	6.82 ± 0.78	6.95 ± 1.66	5.50±1.42	P = 0.35 <sup>NS</sup>	5
Nitrites (mg/l)	71.18 ± 12.03	61.88 ± 17.67	66.23 ± 17.77	72.28 ± 16.76	55.03±8.77	P = 0.28 <sup>NS</sup>	50
Sulphates (mg/l)	99.08 ± 72.98	129.28±53.61	123.83±71.92	124.67±57.48	87.33±65.87	P = 0.74 <sup>NS</sup>	200
Chlorides (mg/l)	138.33±53.19	144.67±55.90	107.83±48.85	111.00±47.12	105.67±48.0	P = 0.54 <sup>NS</sup>	250
Calcium (mg/l)	54.50±9.63	51.67±9.71	56.50±10.93	55.67±10.05	38.67±5.79	P = 0.02 <sup>S</sup>	75
Magnesium (mg/l)	44.70 ±14.47	51.17±7.73	47.33 ±6.41	44.33±11.20	42.29±8.46	P = 0.58 <sup>NS</sup>	50

\* $\alpha = 0.05$  \*\*Superscripts NS = No significant difference \*\*\*S = Significant difference \*\*\*\* Values = mean ± standard deviation

**Table 4: Composition and Average Number of Macroinvertebrates in the Study Area and their Family Tolerance Levels**

PHYLUM	CLASS	ORDER	FAMILY	SPECIES	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>4</sub>	L <sub>C</sub>	TOLERANCE LEVEL	
Arthropoda	Malacostraca	Decapoda	Potamonautidae	<i>Potamonautes reidi</i>	2	7	5	6	4	6	
	Insecta	Odonata	Aeshnidae	<i>Anax junius</i>	1	4	3	3	2	3	
			Libellulidae	<i>Erythrodiplax fusca</i>	2	9	9	12	6	9	
	Diptera		Arthericidae	<i>Ibisia marginata</i>	0	4	5	0.6	4	2	
		Chironomidae	<i>Chironomus aberratus</i>	2	8	6.5	10	11.3	8		
		Typulidae	<i>Aurotipula clara</i>	1	1.7	3	9	11	3		
		Plecoptera	Perlidae	<i>Agneta gladiata</i>	2	8	11	4	12	1	
	Coleoptera	Megaloptera	Elmidae	<i>Elsianus spp</i>	2	2	5	1	3	4	
			Sialidae	<i>Sialis bilobata</i>	3	7.3	6	3	5	4	
	Lepidoptera	Arachnida	Pyalidae	<i>Africella amydara</i>	1.3	3	4	8	4	5	
			Trombidiidae	<i>Trombidium holosericeum</i>	2	5	7	6	5	4	
	Mollusca	Gastropoda	Basommatophora	Ancylidae	<i>Ferrissia dalli</i>	1	6	3	5	4	6
	Platyhelminthes	Turbellaria	Tricladida	Planariidae	<i>Planaria dactyligera</i>	2	11	10	9	6	4
<b>Total No of Individuals</b>					21.3	77	77.5	76.6	77.3		



**Fig. 2: Water Quality and Macroinvertebrates Family Biotic Indices of Hadejia-Nguru Wetlands during**

#### 4. Discussion

Hadejia-Nguru wetlands were found to be slightly acidic with only the control location falling within the WHO standards. This could be as a result of excessive Nitrogen from fertilizer application and other acidic chemicals such as pesticides which have become much available to farmers in the area as observed by Haladu and Bello (2014). Low water pH has been linked to increased solubility and toxicity of substances as well as causing irritation to the eyes, skin and mucous membranes (Ezekwe *et al.*, 2017). Lower DO and higher BOD than the WHO standards during the period of this research indicated contamination of the water from organic sources while TDS and EC above the WHO standards point to the fact that organic and inorganic substances in the wetlands have dissolved in the water. Though TDS is considered a secondary water quality, an elevated concentration thereof may cause water to be corrosive, have salty or brackish taste and result in scale formation among others (Orewole *et al.*, 2007). Turbidity also exceeded the WHO limit in all sampling locations including the control during this study which could result from incessant human activities such as irrigation, fishing, sand packing, natural resources harvesting etc in the area that disturb the water. High turbidity significantly reduces the aesthetic quality of a water body leading to negative impacts on recreation and tourism as well as increasing the cost of water treatment and inhibiting photosynthesis by blocking sunlight (Ronald 1974). Other physicochemical parameters include sulphates, chlorides, calcium and magnesium were found to be within the WHO limit and generally no significant difference exist among sampling locations due to similar human activities in the area.

Macroinvertebrates in Hadejia-Nguru wetlands during this study consist of 13 species about 85% of which are arthropods that have either exoskeleton, wings, specialized mouthparts for feeding or high pollution tolerance index, making them well adapted for life in the area. Abubakar *et al.*, (2015) recorded 20 aquatic insect species during their study on the preliminary survey of the diversity of insects of Hadejia-Nguru wetlands. They identified factors such as drought, pollution, macrophyte cover and nature of substratum to affect the diversity and species richness in the area. About 69% of the 13 macroinvertebrate species identified in this study have pollution tolerance levels  $\geq 4$  which is an indication that the wetlands are highly polluted. Abubakar and Murtala (2015) studied the effects of physicochemical factors of water on Macroinvertebrates' distribution in Hadejia-Nguru Wetlands and found 13 species dominated by Arthropoda and Mollusca. They concluded that the altered physicochemical characteristics of the water together with growing occurrence of the pollution indicator species point to the fact that the wetland is tending towards eutrophication.

The weighted arithmetic water quality index showed a decreasing order of  $L_1 > L_2 > L_3 > L_4 > L_C$  with water samples from all locations being unsuitable for drinking including the control. The macroinvertebrates family Biotic Index of Hadejia-Nguru wetlands followed same pattern with  $L_C$  falling into good water category and other sampling locations being fair, indicating high degree of organic contamination. This is a serious cause of concern to the inhabitants of the area, authorities, researchers, local and the international interest groups due to the importance of the wetlands as a source of livelihood and an overwintering site for some migratory birds. Austine (2020) in his study on macroinvertebrates' structural distribution in a dam within Hadejia-Nguru wetlands revealed that incessant anthropogenic activities and high density of *Typha* grass (*Typha angustifolia*) have a deteriorating effect on the structural composition, abundance and diversity of macroinvertebrates in the area, with only the pollution tolerant species surviving in most cases. Nigerian Conservation Foundation (NCF) 2021 observed upstream hydrological developments driven by irrigation projects as threats that degrade while Abubakar *et al.* (2016) identified climate change as a very important factor affecting the water and its associated biota in Hadejia-Nguru wetlands. They observed that the most obvious manifestation of climate change in Hadejia-Nguru wetlands is the steady increase in both water and atmospheric temperature and posited that though climate change is global in its cause, its consequences are far more reaching in developing countries.

#### 5. Conclusion

Studies on the water quality and macroinvertebrates assessment of Hadejia-Nguru wetlands is an eye opener to the environmental effects of the nefarious human activities taking place in the area. The importance of the area has been stressed while it was found out that the water was contaminated using both the weighted arithmetic water quality index and the family biotic index. There is therefore the need to regulate human activities such as irrigation, excessive fertilizer and pesticides application, and many others while further research is needed for continuous monitoring of the water quality.

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