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Ecological status of a tropical river in Niger delta area of Nigeria, using aquatic insects

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Freshwater ecosystems are the major source of water, being used for domestic, agricultural and industrial purposes. Water bodies are subjected to anthropogenic activities leading to degradation of the water quality. The aim of this study is to assess the health status of Isiokpo River. Aquatic insects were sampled from March to August 2017. Physico-chemical parameters were examined using standard laboratory procedures. A total of 21 taxa comprising of 543 individual insects were recovered. Stations 1, 2 and 3 recorded 53.41, 21.36 and 25.23% of the insect population respectively. A total of six Ephemeroptera, Plecoptera and Trichoptera (EPT) species were recorded in the study. The %EPT was 28.57, 33.33 and 30.77% in station 1, 2 and 3 respectively. There were significant differences in the distribution of dissolved oxygen, phosphate, nitrates transparency, flow velocity, and total dissolved solids across the various stations ($p<0.05$). The reduced level of dissolved oxygen in station 3 as well the dominance of Chironomus sp. are indications of the impact of anthropogenic activities. The study showed that the Isiokpo River is relatively unhealthy.

Key words: Aquatic insects, Biomonitoring, Freshwater, Ephemeroptera, Plecoptera, Trichoptera, Water quality.

INTRODUCTION

Insects, over the years are used as indicators for changes in aquatic ecosystem caused by disturbances such as pollution from domestic, agricultural and industrial wastes, including effluents. The aquatic ecosystem, particularly rivers are regular characteristics of many landscapes which constitute great socio-economic importance to humans; prevision of vast regional freshwater biodiversity (Dalal and Gupta, 2015), and goods and services essential to human communities globally (Adu and Oyeniyi, 2019).

Water pollution threaten aquatic biodiversity (Haggag et al., 2018), degrade water quality (Koff et al., 2016) and impact the ecosystem adversely. The growing use of macroinvertebrates, including insects to access the health status of freshwater ecosystem (Valente-Neto et al., 2018; Miguel et al., 2017). The use of insects become necessary due to their abundance and diversity which dominate freshwater ecosystem (Jooste et al., 2020). Insects are the most directly affected group that vulnerable to any disturbance or pollution in the aquatic

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ecosystem due to their diversity and abundance (Selvanayagam and Abril, 2016).

In the Niger Delta region of Nigeria, tropical rivers such as the Isiokpo river located near an abattoir and used by humans for bathing, laundry and fishing may have been stressed and impacted. Investigation on the impact of such stressors on the ecological status of the river is yet to be determined and this provides the basis for this present study with an aim to assess the health status of Isiokpo River using entomofaunal assemblage and biodiversity.

MATERIALS AND METHODS

Research design

The study was conducted at River Isiokpo which was divided into three stations based on the relative level of human activities; Station 1 is upstream and is characterized by very little or no human activities.; Station 2 is midstream and characterized by relatively moderate human activities which includes bathing and fishing while Station 3 is downstream with relatively high human activities which includes bathing, laundry and fishing with a market nearby, abattoir and waste dump. The study area covered a total area of 3,540 m^2 with the low, moderate and high impacted stations separated from each other by 1.5-2 km. Each station was divided into four substations using biotopes as criteria within a completely randomized design.

The Isiokpo River is located in Isiokpo town. Isiokpo is the headquarters of Ikwerre Local Government Area of Rivers State in the Niger Delta Area of Nigeria and lies within Longitude 4°56'N-5° 0'N and Latitude 6°51'E - 6°52'E (Figure 1). The vegetation is tropical rainforest plant species dominated by trees and shrubs such as Raphia palm - *Raphiahookeri*, Ferns, Bamboo – *Bambusa* sp., *Alchorneacardifolia*, Oat Grass -*Acroceraszizanioides,* Elephant grass – *Pennisetum purpureum*, Water Lily - *Nymphaealotus,* etc*.* The area is characterized by high relative humidity (80-92%), with an average annual rainfall of approximately 2800 mm (Njoku et al., 2019). There are two seasons in the study area: rainy and dry seasons. The rainy season is typically from the month of April to October, while the dry season is usually from November to March. The average temperature is about 28°C (Adejuwon, 2018).

Sample collection

Aquatic insect collection

Insect samples were collected monthly for six months using a rectangular frame and triangular frame dipnet and a kick net with mesh size of 500 µm. For insect sampling of the water surface, the rectangular-frame net was swept over the water surface and then turned to prevent captured insects from escaping. For sampling in the vegetation, the dipnet is jabbed under floating vegetation that are undisturbed, the vegetation was then shaken to dislodge organisms from the vegetation and sediments. Collection by kick-net was done by holding the net against water current and the leg is used to kick three times at about an area of 1 m^2 in front of the net for one minute. Collected samples were preserved in 70% alcohol and transported to the Entomology Research Laboratory of the University of Port Harcourt for sorting and identification. In the laboratory, samples were washed in a 250 µm mesh size filter to remove debris while aquatic insects were carefully picked with the aid of forceps and a masticated toothpick and placed in separate labelled vials containing 70% ethanol. Sorted insects were identified to genus level using the keys (Badawy et al., 2013; Mahmoud and Riad, 2020).

Water physico-chemical sampling

Water samples used for the analysis of chemical variables were collected monthly in 250 ml plastic bottles for six months (March 2017 – August 2017). Dissolved oxygen (DO) was measured using JPB-607A DO Analyzer while pH, conductivity, total dissolved solids (TDS) and oxidation reduction potential (ORP) were measured using SPER Scientific 860033 Benchtop; calibrated handheld pH electronic meter (D1-4337), electronic conductivity meter model (H1-4103)Transparency was measured using a secchi disk Water Quality Meter. (Haggag et al., 2018; Mahmoud and Riad, 2020), Flow rate was measured using a timed float as it moved over a distance of 10 m (Adu and Oyeniyi, 2019). Total nitrates and phosphates concentrations were measured spectrophotometrically using standard methods (Calibrated HACH 3900DR spectrometer, TDS by calibrated handheld electronic TDS meter D4-7103).

Data analysis

Results were descriptively analyzed and represented with tables and charts using Microsoft Excel. Physicochemical parameters of sites were compared using one-way ANOVA. Calculated means were compared using the Tukey Honest Significant Difference (HSD) test to assess the significant differences in aquatic insects abundance and distribution in relation to physiochemical parameters measured among the studied sites, with level of significance set at $P<0.05$.

Species diversity indices

Species diversity index comprising; Simpson dominance (D), Shannon-Weiner index(H) and Evenness index(E) were used to analyze species diversity, distribution and richness among study stations in the river. Percentage composition of species of three orders of insects: Ephemeroptera, Plecoptera and Trichoptera (%EPT) was calculated using number of EPT species collected from the respective sampling stations in the formula (Hamid and Rawi, 2017).

$$\%EPT = \frac{\text{No of EPT species}}{\text{Total No of Species collected}} \text{ x } 100$$

Simpson dominance $D = £(Pi)^2$ Shannon-Weiner Index $H = \frac{^{s}£ (Piln(Pi))}{X}$

Evenness Index $E = \frac{H}{Ln(S)} = \frac{Ln(N^1)}{Ln(No)}$

RESULTS

Variations in physico-chemical parameters

Physico-chemical parameters vary in concentrations among the various stations, for example, parameters such as temperature, conductivity, pH mean values were

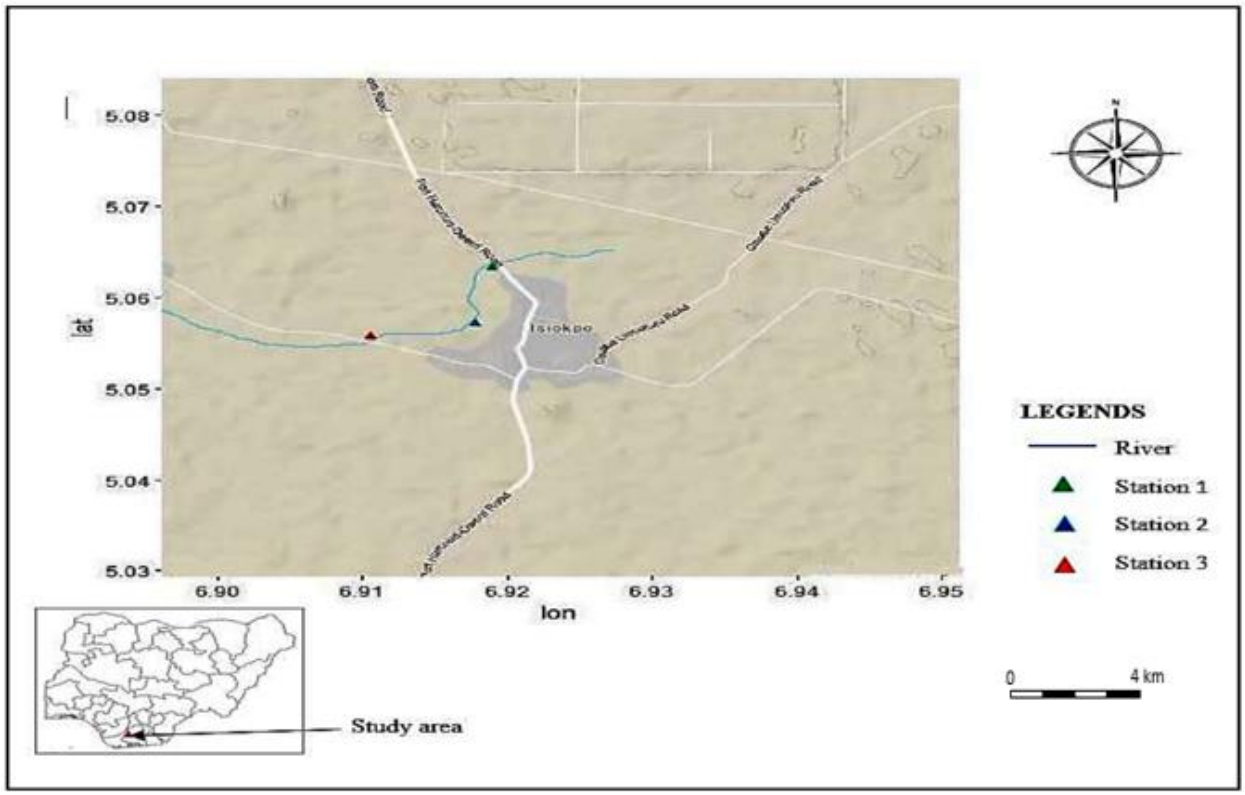

Figure 1. Map of study area with sampling stations.

Table 1. Mean ± Standard error of Physico-chemical parameters measured in Isiokpo River.

Parameter	Station 1 Least human impact	Station 2 Moderate human impact 2	Station 3 High human impact 3
Temperature (°C)	24.5±0.55[a]	24.67 ± 0.52[a]	25.67 ± 0.75[b]
Dissolved Oxygen (mg/l)	5.87 ± 0.12[a]	5.38 ± 0.15[b]	4.40 ± 0.22[c]
pH	7.19 ± 1.03[a]	7.4 ± 0.93[a]	7.24 ± 0.7[a]
Conductivity (µS/cm)	29.54 ± 2.28[a]	19.90 ± 4.49[a]	34.52 ± 2.65[a]
Phosphates (mg/l)	0.14 ± 0.00[a]	0.13 ± 0.01[b]	0.14 ± 0.00[c]
Nitrates (mg/l)	0.14 ± 0.01[a]	0.12 ± 0.01[a]	0.18 ± 0.04[b]
Transparency (cm)	54.00 ± 0.89[a]	45.67 ± 1.37[b]	36.00 ± 3.63[c]
Flow rate(cm/s)	0.31 ± 0.01[a]	0.15 ± 0.03[b]	0.22 ± 0.02[c]
TDS (ppm)	10.54 ± 1.13[a]	12.55 ± 2.99[a]	43.86 ± 41.64[b]
ORP (mv)	145.34 ±65.70[a]	151.86±6.97[a]	158.07±11.35[a]

Means with the same superscripts in a row are not significantly different (P<0.05).

higher in highly human disturbed sites (Station 3) than lowly human disturbed sites (Station 1) (Table 1). Contrarily, transparency and flow rate were higher in lowly disturbed station than highly distributed station. On chemical parameters, dissolved oxygen and phosphates concentration were higher in lowly disturbed station than highly disturbed station (Table 1). The mean concentrations of Nitrates and total dissolved solids (TDS) were all higher in the highly disturbed than lowly disturbed stations. In the moderately disturbed station (Station 2), mean temperatures, dissolved oxygen, pH and TDS were slightly higher than those of lowly disturbed station.

Statistically, no significant difference in concentration in some physic chemical parameters across the three

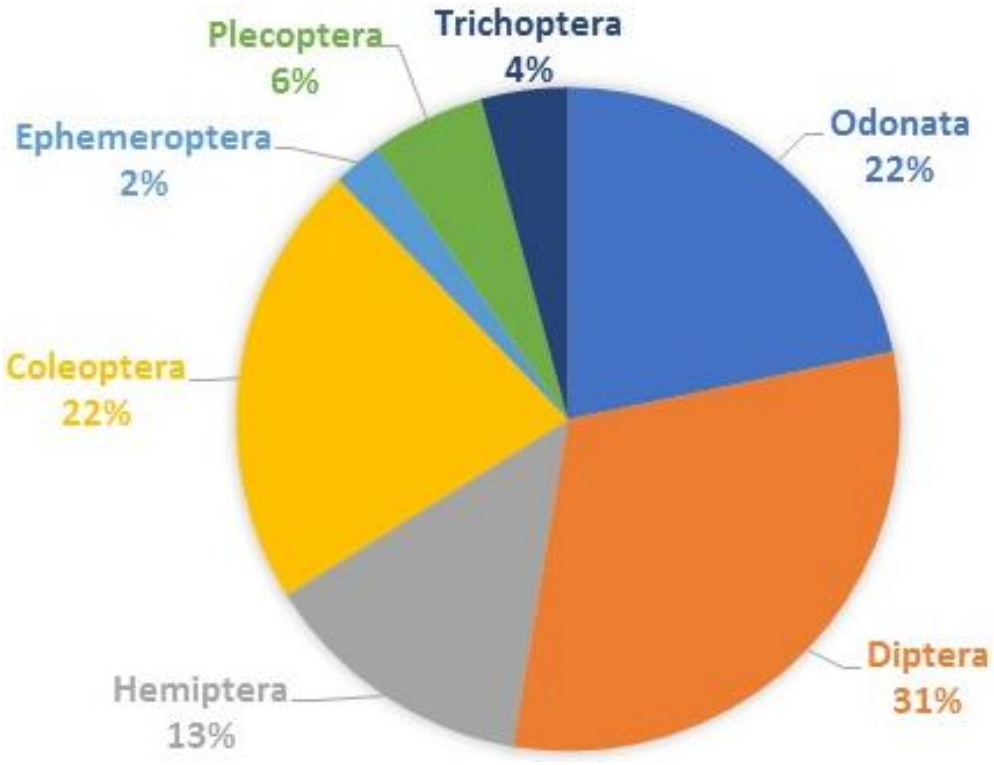

Figure 2. Percentage composition of Insect Orders at Isiokpo River, Rivers State, Nigeria.

stations was recorded. The parameters are pH, conductivity, ORP values. There was significant difference in parameters such as dissolved oxygen, phosphates, transparency and flow rate across the three stations (Table 1). Similarly, significant differences occurred in concentration of TDS, Nitrates, temperatures between lowly- and highly- disturbed stations, but did not occur between lowly and moderately disturbed stations (Table 1).

Community composition

At the end of the study a total of 543 insect individuals were collected and identified into twenty-one species, belonging to seven orders and fifteen families at the Isiokpo River. The major percentage of insects occurred in the order Diptera (30.94%), followed by equal insect abundance 21.73% of Odonata and Coleoptera Hemiptera (13.43%), Plecoptera (5.52%) Trichoptera (4.24%) Ephemeroptera (2.39%) (Figure 2).

Insect abundance and distribution among the three stations was low human impacted station (Station 1) (290 individuals, 53.41%), moderately impacted station (Station 2) (116 individuals, 21.36%), and highly impacted station (Station 3) (137 individuals, 25.23%) (Figure 3). Figure 4 indicates that Diptera among the seven orders of insects encountered at Isiokpo River recorded more abundance and Ephemeroptera least abundance (Figure 4). It also indicates that stations 1 recorded the highest abundance in all the insect orders encountered in the three stations (Figure 4).

Insect orders at Isiokpo River

Figure 3 shows insect abundance among different orders and distribution between three stations at Isiokpo River, Rivers State, Nigeria.

Spatial variations in species diversity indices across sampling stations at Isiokpo River

Results of species richness among stations, indicated that in lowly impacted or disturbed station (Station 1) twenty-one species, moderately disturbed (Station 2) fifteen, and highly impacted thirteen species were encountered. Abundance among the stations was 290 individuals (Station 1), 116 individuals (Station 2) and 137 individuals (Station 3) (Figure 5). Statistical analysis on species distribution, and evenness across the three stations indicated an increasing dominance index of species; 0.8725 (Station 1) 0.8847 (Station 2) 0.7697 (Station 3) (Table 1). The Shannon-Weiner diversity indices was higher at Station 1 with values of 2.4351 and

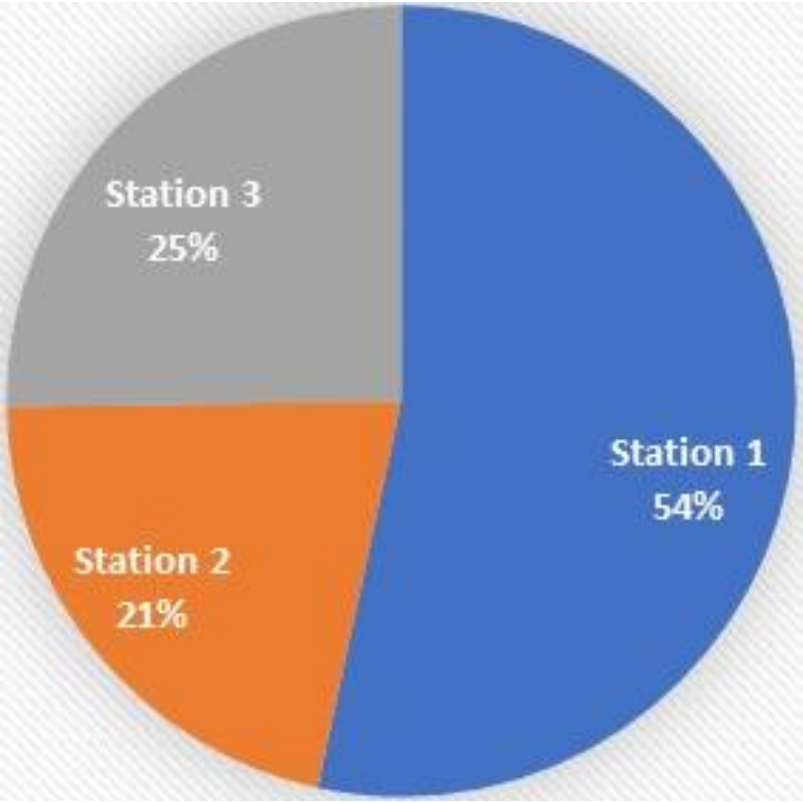

Figure 3. Percentage abundance of insects between three different stations at Isiokpo River, Nigeria.

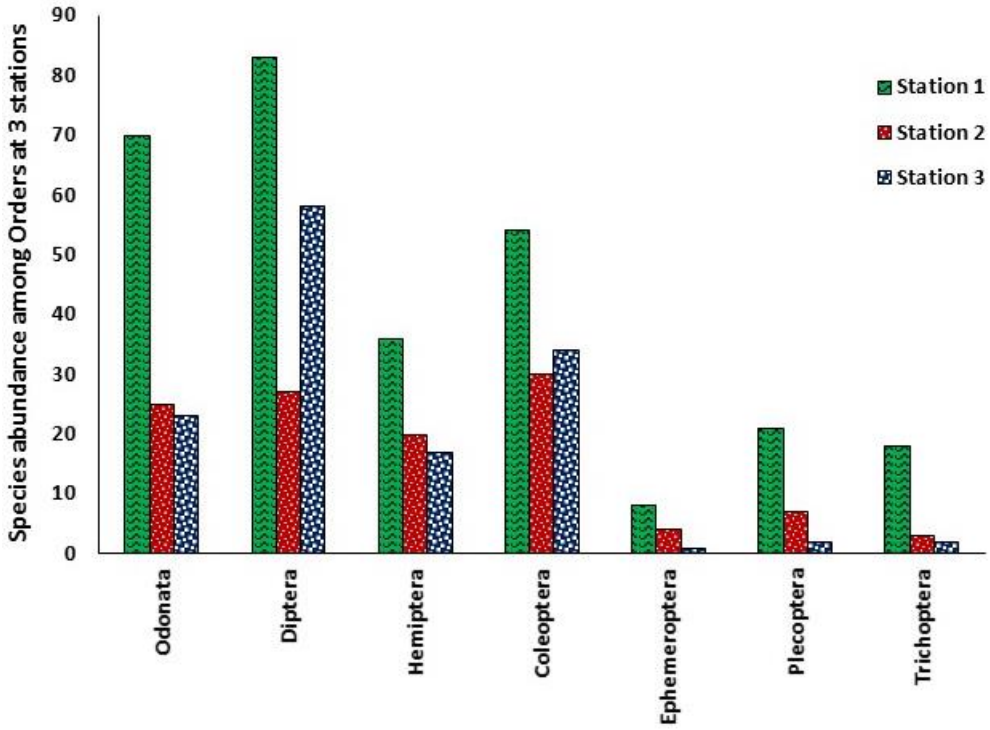

Figure 4. Diptera among the seven orders of insects encountered at Isiokpo River recorded more abundance and Ephemeroptera least abundance.

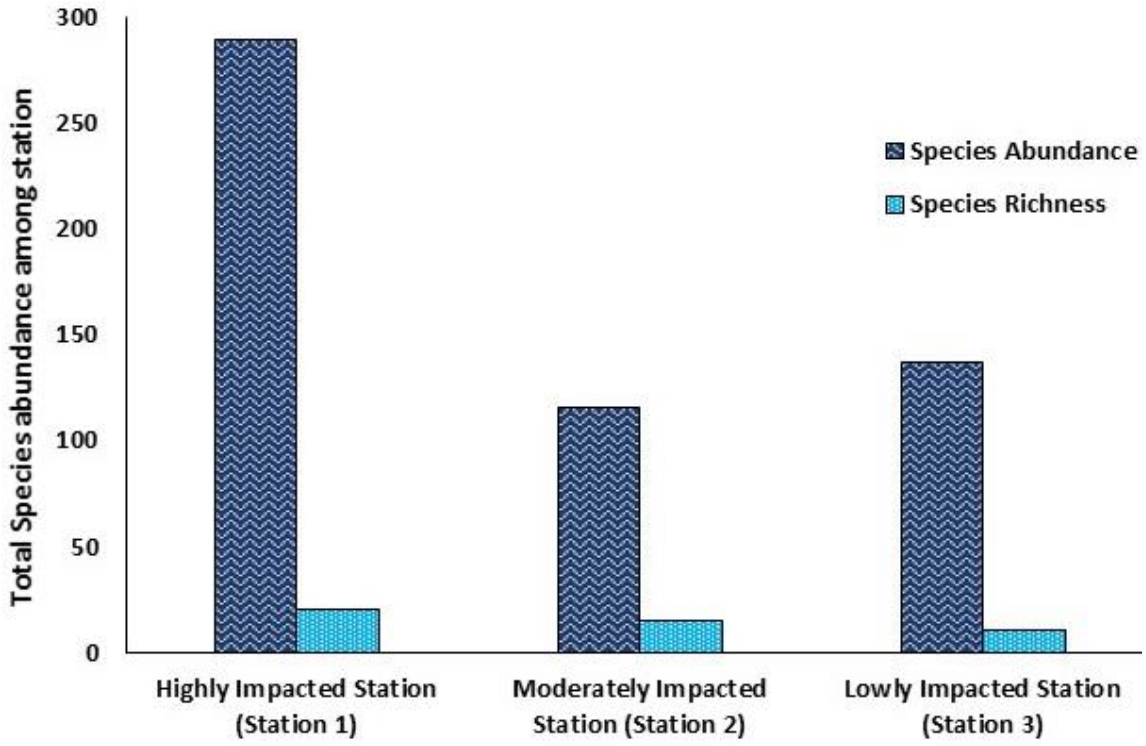

Figure 5. Total species richness and abundance among the three stations at Isiokpo River, Rivers State, Nigeria.

Table 2. Species diversity indices across sampling stations in Isiokpo River, Rivers State, Nigeria.

Indices	Station 1	Station 2	Station 3
Taxa	21	15	13
Individual	290 (53.41%)	116 (21.36%)	137 (25.23%)
Simpson index (D)	0.8725	0.8847	0.7697
Evenness (E)	0.5438	0.7097	0.5002
Shannon-Weiner (H)	2.435	2.365	1.872

least at station 3 with values of 1.872 (Table 2).

Indicator species

Results of bioindicator species (or taxa) that belong to three orders of insects; Ephemeroptera, plecoptera and Trichoptera in Isiokpo River showed that out of a total of six species encountered, three belong to Ephemeroptera, one to Plecoptera and two species to Trichoptera (Table 3). The percentage EPT distribution of Isiokpo River at the period of study was 40% (Station 1), 33.3% (Station 2) and 26.7% (Station 3) (Table 3).

A total of sixty-six EPT individuals were encountered with the highest recorded at Station 1 and least at Station 3 (Table 3). Out of the three Ephemeroptera species encountered, only one; Ephemera sp occurred at Station 3. Eight out of twenty-one species encountered during the study were absent at Station 3 and six did not occur at Station 2 (Table 4). Eleven species comprising all the four species of Coeloptera and seven other species were encountered across the three stations (Table 4).

DISCUSSION

Community composition of insect species recorded at the Isiokpo River in this study gives an indication of the ecosystem health of the river because it is in accordance with the fact that the quality of water is examined by comparing the number of tolerant and intolerant insect species (Gogoi and Guha, 2000). At the Isiokpo River, Station 1 which is less impacted by human activities contained more species than the highly impacted station

Table 3. EPT richness across sampling stations in Isiokpo River.

Species	Station 1	Station 2	Station 3
Ephemeroptera			
Baetis sp	3	3	0
Caenis sp	3	1	0
Ephemera sp	2	0	1
Sub-total	**8**	**4**	**1**
Plecoptera			
Neoperla sp	21	7	2
Sub-total	**21**	**7**	**2**
Trichoptera			
Hydropsyche sp.	15	2	1
Leptonema sp.	3	1	1
Sub-total	**18**	**3**	**2**
Total EPT species	6	5	4
No. of EPT individuals	47	14	5
%EPT	40	33.33	26.46

3, thus it is ecologically healthier. The abundance of species recorded in the three stations also add credence to the ecological status of the river as Station 1 is more abundant than others. The high abundance of species recorded at Station 3 over the moderately impacted Station 2 is due to the high abundance of tolerant species recorded at Station 3. The Isiokpo River harbor eleven tolerant species which occurred through the three stations, and *Chironomus* sp (Diptera), *Baetis vagans*, *Cybister* sp, *Gyrinus* sp., and *Agabus* sp (Coleoptera). Out of them occurred in large number of individuals, particularly in the higher impacted station 3. The increase in the number of individuals at Station 3 indicates that they have the ability to tolerate the pollution caused by high human activities. It has been stated that higher concentrations of organic and/or inorganic pollutants decreased chironomid larvae, but increased the abundance of tolerant species, which are mainly Chironomus spp (Salman et al., 2010). Our study agrees with this, however, the high abundance of Chironomids at low impacted station 1, indicates that some species occur in clean and moderately polluted water. These two categories of chironomids were encountered in our study, though the category that tolerated low polluted or impacted station was higher at Isiokpo River. This agrees with Salman et al. (2010) that those chironomids which have the "ability to survive in extreme environmental conditions with low dissolved oxygen and high concentrations of pollutants are considered tolerant species", while some species occur in clean water. The two categories encountered tolerated low and high dissolved oxygen of station 3 and 1, respectively, indicating that station 3 has higher level of anthropogenic activities, particularly as DO value was below WHO Standard minimum limit for optimum aquatic productivity (5.0 mg/L) (Esenowo et al., 2015).

The low flow rate recorded at Station 3 indicates that mixing of water was slow as compared to Station 1 due to accumulation of pollutants caused by high impact of human activities. This caused reduced pH and transparency at Station 3, leading to low distribution of species. Human activities leading to discharges through run-offs from refuse dumpsites and nearly abattoir into rivers caused organic pollution and reduced dissolved oxygen (Elemile et al., 2019; Folami et al., 2019). The situation at Station 3 in our study is in conformity with this report.

Hamid and Rawi (2017); Savic et al. (2017) reported that freshwater insect species belonging to three orders; Ephemeroptera, plecoptera and Trichoptera (EPT) are used as indicators of health status of freshwater bodies due to their response (presence, absence, abundance and distribution) to environmental changes. In our study, the %EPT species recorded showed that Station 3 (26.7%) is relatively low, indicating that the station is polluted.

Edeghene (2020) stated that water bodies with Margalef's water quality index values of greater than 3 is an indication of clean water conditions. In our study, Station 1 had an index value of 3.527 while Station 3 showed 2,439 indicating that our study agrees with the report.

CONCLUSION AND RECOMMENDATION

The high human activities of the Isiokpo River has impacted much on Station 3, with a reduced diversity of

Table 4. Insect species distribution in the three stations.

Orders	Species	Station 1	Station 2	Station 3
Odonata	*Aeshna* sp.	9	8	5
	Hemistigma sp.	1	0	0
	Libellula sp	57	17	17
	Enallagma sp.	3	0	1
	Sub-total	**70**	**25**	**23**
Diptera	*Chironomus* sp.	72	24	58
	Culex sp.	3	3	0
	Aedes sp.	8	0	0
	Sub-total	**83**	**27**	**58**
Hemiptera	*Gerris* sp.	14	15	17
	Belostoma sp.	20	5	0
	Nepa sp.	1	0	0
	Lethocerus americanus.	1	0	0
	Sub-total	**36**	**20**	**17**
Coleoptera	*Hyphydrus sp*	11	14	14
	Cybister sp.	22	8	10
	Gyrinus sp.	12	6	6
	Agabus sp	9	2	4
	Sub-total	**54**	**30**	**34**
Ephemeroptera	*Baetis vagans*	3	3	0
	Caenis simulars	3	1	0
	Ephemera sp.	2	0	1
	Sub-total	**8**	**4**	**1**
Plecoptera	*Neoperla* sp.	21	7	2
	Sub-total	**21**	**7**	**2**
Trichoptera	Hydropsyche sp.	15	2	1
	Leptonema sp.	3	1	1
	Sub-total	**18**	**3**	**2**
	TOTAL	**290 (53.41%)**	**116(21.36%)**	**137(25.23%)**

insect species, including EPT species and changes the ecological health status of the River. The Station 1 of the River still have a relatively diverse aquatic insect fauna and low human impacts compared to Stations 2 and 3. The diverse aquatic insect fauna pointed out that Station 1 is relatively healthy. We wish to recommend that adequate water management program be introduced into the river to control the continuous and uncontrolled activities around the river in order to conserve its insect fauna inhabitants and its dependable organisms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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