Assessment of the structure of the macroinvertebrate community in the lower Section of the River Adofi, Nigeria.

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Abstract

This study assessed the macroinvertebrate community structure of the Adofi River at three (3) ecologically distinct stations by collecting water samples in plastic containers and macroinvertebrate samples using a D-shaped net for 12 months, from December 2020 – November 2021 and analysed in the laboratory using standard methods. The results of physico-chemical parameters ranged between: air temperature (27-32) °C, water temperature (26-30) °C, pH (2.1-7.4), dissolved oxygen (5.4-9.8) mg/L, water depth (59-154.2)cm, alkalinity (180-280), conductivity (102-132.5) µs/cm, acidity (48-76) mg/L, TDS (80-130) mg/L, phosphate (1-3) mg/L, sulphate (204-52) mg/L, and nitrate(14.5-26.4) mg/L. ANOVA analysis showed that water depth, alkalinity, and sulphate values were statistically significant between the three sampled stations at $P \leq 0.05$. 777 macroinvertebrate organisms ranging from *Coleoptera, Hemiptera, Odonata, Gastropoda,* and *Arachnida*, were collected in this study. *Hemiptera* dominated with 452 individuals and accounted for 58% of the macroinvertebrate group, and *Odonata* was the least with 39 individuals. *Gerris lacustris* dominated, while *Ilyocoris cimicoides* was least abundant and found only in station 1. The CCA triplot showed that D.O, water depth, TDS, and BOD supported the abundance of *Dolomedes* sp., *Pseudomacronucleus* sp., and *macromiidae* sp. in station 1.

Keywords: Macroinvertebrate, Diversity, Abundance, Distribution, River Adofi

Introduction

Over 80% of the wastewater generated by communities worldwide is returned to aquatic ecosystems without being treated or reused, discharging chemical and biological toxins into water bodies; and constituting a threat to aquatic and other water-dependent life (McGoff et al. 2013). Freshwater is a valuable and scarce resource that is susceptible to comtaminationfrom harmful human activities. When freshwater systems become degraded due to the impacts of anthropogenic activities and progress to the extent they can be considered "polluted", the quality becomes difficult and costly to restore their quality. In order to prevent this, regular monitoring of the aquatic habitats, particularly the freshwater environment, is required (UN-water. 2016). Many freshwater organisms have been used in biological monitoring, including bacteria, algae, vascular plants, macroinvertebrates, and fish. Of these organisms, macroinvertebrates, including molluscs, crustaceans, annelids, and insects, are frequently recommended for biomonitoring programmes because of their diversity, ease of collection, and ease of identification to levels needed for bioassessment (Iyagbaye et al., 2017), as well as, being sensitive to changes in water quality, habitat conditions, and other environmental stressors makes them crucial indicators of the health of these ecosystems (Iloba et al., 2018).

For many decades, water from the Adofi River has served the domestic, recreational, and agricultural needs towns of bordering its banks while also meeting individuals' spiritual needs by serving as a place of ancestral worship for residents of these communities. Ikomi et al. (2003), Arimoro (2009), Iloba and Akawo (2013), and Akporido et al. (2018) have offered information about this significant River. However, none of these studies was conducted on the lower section of this River, which is the focus of this study, especially regarding the community structure of its macroinvertebrate community. This research aims to assess the macroinvertebrate community structure of the lower section of the River Adofi at Ossissa.

Description of the Study Area.

River Adofi (Figure 1) is a first-order river that flows from Ejeme-unor in the Aniocha South local government of Delta State, through Ejeme-aniogor in the Aniocha South Local Government area to, to Utagba-Uno. It swings south-eastwards to Ossissa to join the Ase River in Delta State, Nigeria. The river is vital to the surrounding communities, as it is the only river draining the area.

The river provides water for domestic and agricultural use to the inhabitants of the surrounding communities. It lies within the dense and thick tropical rainforest at a terrain elevation of 22m above sea level. Fish found in this river include *Bagrus bayad, Oreochromis niloticus, Oreochromis aureus, Gymnarchus niloticus*, and some members of the families, *Mokochidae* and *Clariidae*. Anthropogenic activities include fishing, washing clothes, bathing, fermentation of cassava, lumbering, etc.

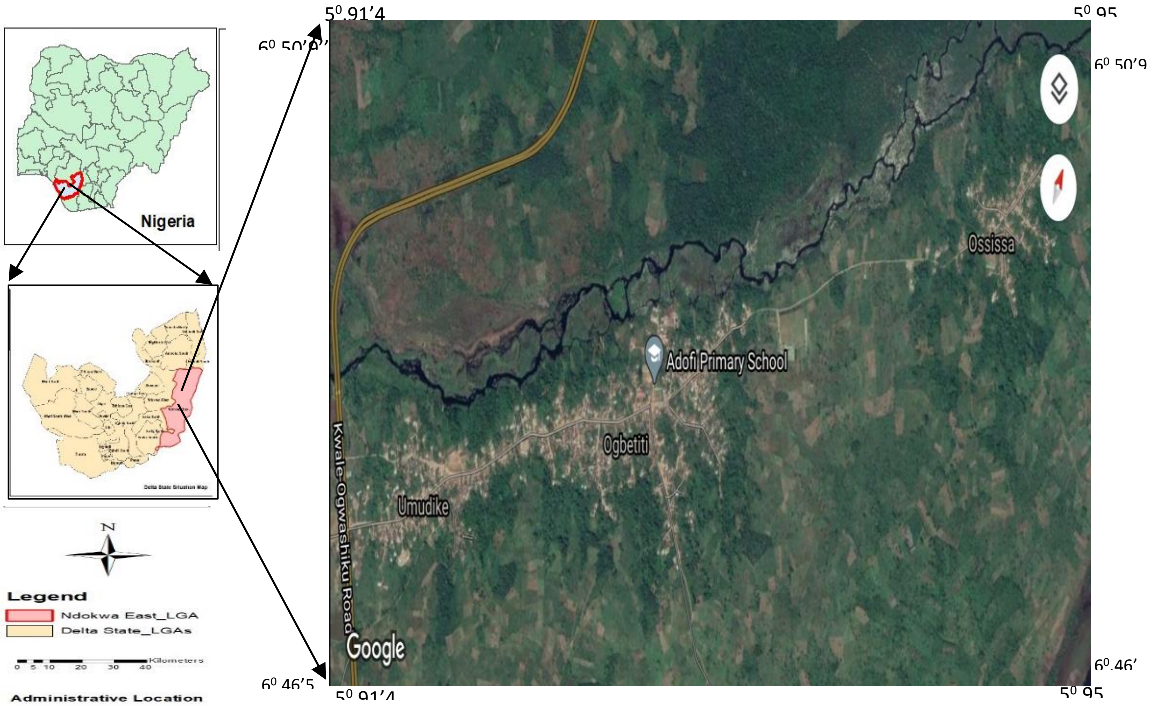

Figure 1: Map showing the river course of River Adofi at Ossissa showing the sampling stations at Umudike, Ogbe-etiti, and Ossissa. Source: Google map imagery (2021).

Description of sampling sites.

To ensure that a wide range of the river system is encompassed, the study identified three sampling stations based on the level of vegetation cover, human activities, and ecological attributes of the stations. The stations are at; Umudike, Ogbe-Etiti, and Umueze communities in the Ossissa clan, representing stations 1, 2, and 3, respectively.

Station 1(Umudike): This is located on longitude 5.914, and latitude 6.465, about ten (10m) metres before River Adofi bridge at Ossissa, on Kwale /Ogwashi-ukwu expressway. The station is characterized by rich vegetation cover, and provides water for domestic use, and the current is swift.

Station 2(Ogbe-etiti): This is a backwater region cut off from the main water channel by dense aquatic vegetation. However, the littoral vegetation is absent due to canoe anchorage, located at a longitude of 5.928 and a latitude of 6.484, and characteristically providing water for domestic use, discharge of cassava effluents into the water body.

Station 3(Umueze): This is the farthest of the three stations and it is located at longitude 5.950 and latitude 6.509, approximately two (2) kilometres away from the mouth of the river, where it empties into the Ase River. Although like station 2, it is a backwater zone, the water is used as a source for drinking, washing, swimming, Anchorage, cassava fermentation, and a point of religious activities for local folks that worship the river deity. The riparian zone and adjourning land are used for agricultural activities, serving as farmlands for local cassava farmers.

Macro-invertebrate sample

The "kick sampling technique" described by Lenat *et al* (1981), adopted by Ikomi et al., (2005) and also Iloba et al (2019), was used in collecting macroinvertebrates from the bank root biotope of each station. In this method, the substratum and the emergent vegetation were vigorously disturbed by kicking upstream. The dislodged animals from the streambed were washed by the current into a D-shaped net held against the flow direction and used to collect them. This same methodology was repeated at three additional points in each station to ensure that each station is effectively sampled. 5% Formalin was then used to preserve the macrobenthic samples collected, in a well-labelled containers indicating the; date, time, and name of sampling stations, for onward transport to the Laboratory of the Department of Animal and Environmental Biology, Delta State University, Abraka for further analysis. In the laboratory, samples were washed in a 600-micrometre mesh sieve net to remove silts and debris. The entire sample was identified and enumerated to the lowest practical taxon under a binocular dissecting microscope. Identification was done using keys and references by Day and De-Moor (2002) and Umar *et al.*, (2013).

Statistical Analysis

Past 4.05 statistical software was used to generate Canonical correspondence analysis (CCA), to establish the relationship between environmental and macroinvertebrate abundance at the various sampling stations in the Adofi River. Macroinvertebrate diversity indices were calculated with Margalef's and Shannon-Weiners' diversity Index. The physicochemical parameters were subjected to a One-way ANOVA to ascertain differences between stations. At the same time, cluster analysis was used to establish similarities between sampling stations. Microsoft Excel 2010, was used to plot simple line graphs and bar charts.

Results.

Physico-chemical parameters.

Table 1 is a summary of results of measured physico-chemical parameters of the sampled stations in Adofi River showing Mean ± Standard deviation, and ANOVA values of various parameters, from December 2020 to November 2021 (minimum and maximum values in parenthesis).

Table 1: Measured physico-chemical parameters of the sampled stations in Adofi River

Parameter	Station 1 (Umudike)	Station 2 (Ogbetiti)	Station 3 (Umueze)	F-value	P-value
Air Temp. (^{0}C)	28.25±1.1382 (27-30)	29±1.2792 (27-31)	29.5±1.3817 (27-32)	2.944	0.0666
Water Temp. (^{0}C)	27.17±1.1146 (26-29)	27.92±1.2401 (26-30)	28.17±1.1934 (26-30)	2.319	0.1142
pH	6.97±0.3101 (6.42-7.4)	6.43±1.3917 (2.11-7.34)	6.73±0.1655 (6.4-6.92)	1.278	0.292
Dissolved Oxygen (mg/L)	8.8±1.0436 (7-9.8)	7.97±0.9038 (6.2-9)	8.17±1.2936 (5.4-9.4)	1.903	0.1651
B.O.D(mg/L)	5.15±1.5687 (3.1-8)	4.18±1.4111 (2.2-6.5)	4.64±1.1897 (2-5.4)	1.459	0.2471
Water Depth	138.01±11.1625 (124-154.2)	68.58±8.3850 (59-77.8)	72.18±6.9188 (64-79.6)	226.5	5.30E-20
Alkalinity (mg/L)	235.83±28.1096 (180-280)	202.08±24.6298 (150-220)	186.25±5.6909 (180-195)	16.16	1.28E-05
Conductivity (µS/cm)	116.43±9.8936 (102-132.4)	116.65±3.8216 (112-122)	118.43±4.5795 (110-124.5)	0.3249	0.7249
Acidity (mg/L)	66.83±2.9797 (60-70)	72.25±11.6629 (55-86)	62.33±8.1166 (48-70)	4.211	0.0235
TDS (mg/L)	109.75±23.4758 (80-135)	100.58±11.50 (84-118)	114.67±13.8652 (94-130)	2.101	0.1385
Phosphate(mg/L)	2.00±0.4481 (1.2-2.4)	1.9±0.5205 (1-2.4)	2.24±0.6811 (1-3)	1.161	0.3257
Sulphate(mg/L)	46.44±5.5827 (38-52)	33.76±1.8655 (30.8-36)	31.14±6.8916 (20.4-38)	29.33	4.79E-08
Nitrates (mg/L)	20.85±2.1399 (17-23)	20.47±0.7512 (19-21.5)	22.33±4.0878 (14.5-26.4)	1.601	0.2169

*P<0.05= significant difference; P>0.05=No significant difference.

The result of the analysis of physico-chemical parameters of the sampled stations, as shown in Table 1, clearly revealed there was no significant difference (P>0.05) in the values of the parameters across the various sampling stations except for; water depth, Alkalinity, and Sulphate, which were all significant (P<0.05). Water temperature, pH, D.O., water depth, B.O.D., Alkalinity, Conductivity, Acidity, TDS, phosphate, and sulphate were higher in station 1, while Nitrates were highest in station 3. Cluster analysis revealed that Station 2 and 3, were clustered together, as they were separated by s distance of 0.15, while station 1 is more unique and separated from the other two stations by a distance of 0.35, as shown in Fig. 2

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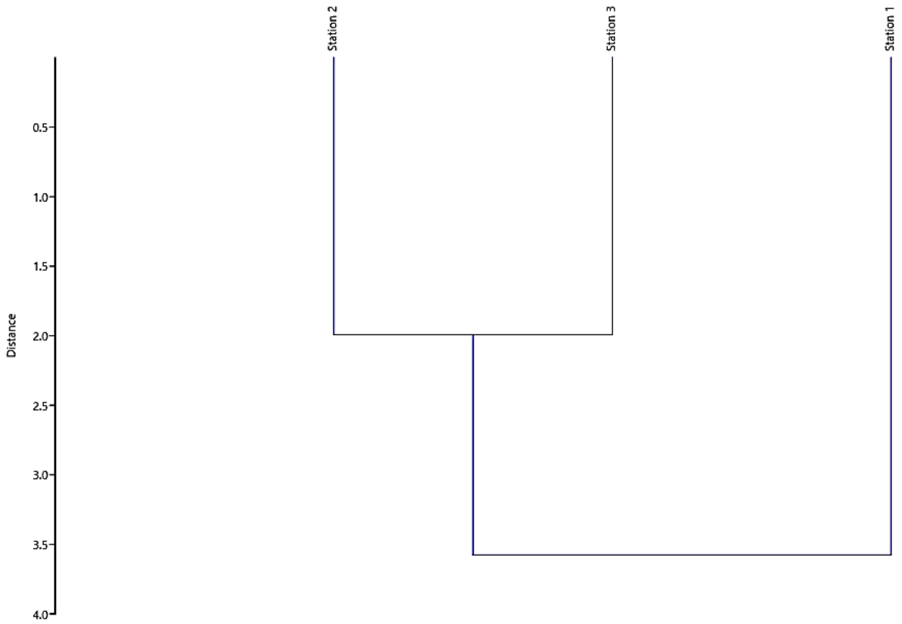

Figure 2: Dendrogram of the cluster analysis of physico-chemical water parameters from the three sampling stations.

Macroinvertebrate Community Structure

Table 2: Checklist showing the composition, and distribution of Macroinvertebrates communities of Adofi River at the three stations.

Taxa	Family	Species	Station 1	Station 2	Station 3	Total	Relative Abundance %
Hemiptera	*Nepidae*	*Ranatra linearis*	+	-	+	93	12.00%
	Gerridae	*Gerris lacustris*	+	+	+	351	45.00%
	Nauciridae	*Ilyocoris cimicoides*	+	-	-	10	1.00%
Subtotal						**454**	
Odonata	*Corduliidae*		+	-	+	27	3.00%
	Macromiidae		+	+	+	12	2.00%
Subtotal						**39**	
Gastropoda	*Planorbidae*	*Bulinus globosus*	+	+	+	59	8.00%
Subtotal						**59**	
Coleoptera	*Hydrophilidae*	*Allocotocerus subaenus*	+	-	+	35	4.00%
	Dytiscidae	*Dysticus marginalis*	+	+	+	68	9.00%
	Gyrinidae	*Gyrinus sp.*	+		+	46	6.00%
	Elmidae	*Pseudomacronychus sp..*	+	+	-	21	3.00%
Subtotal						**170**	
Arachnida	*Pisauridae*	*Dolomedes sp..*	+	+	+	55	7.00%
Subtotal						**55**	
Total			**520**	**83**	**174**	**777**	**100**

From Table 2 above, the composition of macroinvertebrate communities in Adofi River is made up of three (3) insect orders; Odonata, Hemiptera, and Coleoptera, one mollusc order, Gastropoda, and the Arachnida. These organisms belong to eleven (11) distinct families and a total of seven hundred and seventy-seven (777) individual organisms. The hemipterans were most dominant with four hundred and fifty-two (452) amounting to 58% of the total number of organisms. This was followed by Coleoptera 172 individuals (22%), Gastropoda 59 individuals (8%), Arachnida, 55 individuals (7%), and Odonata, 39 individuals (5%). The Gerridae were the most abundant family with 351 individuals, making up 45% of the total macroinvertebrate taxa in the Adofi river. This was followed by *nepidae* 93 individuals, 12%, *dDOytiscidae* 68 individuals (9%), *planorbidae,* 59 individuals (8%), *pisuridae* 55 individuals (7%), *gyrinidae* 46 individuals (6%), *hydrophilidae* 35 individuals (4%), *cordulliidae* and *elmidae* both amounted to 3% each with 27 and 21 individuals respectively, while *macromidae* 12 individuals and *nauciridae* 10 individuals made up the remaining 2% and 1% respectively.

Canonical Correspondence Analysis (CCA)

The CCA triplot is presented in figure 4, The plot shows the main axis (environmental) scored 70.97% of the total variation in macroinvertebrates community assemblage structure, while axis 2, explained the remaining 29.03%. The triplot shows that in station 1 (Umudike), there was a strong positive correlation between DO, water depth, TDS, and BOD. These environmental parameters were found to support the abundance of *Dolomedes* sp. *Pseudomacronuchus* sp. *and the macromidae* sp., alkalinity and acidity influenced the abundance of *Dysticus marginalis, Ranatra linearis, and Gyrinus* sp. in this station. In Station 2(Ogbe-etiti) Sulphate was the sole water parameter at play here, supporting the abundance of *Ilyocoris cimicoides, Allocotocerus subaenus, and cordulidae* sp. while Station3(Umueze) correlated phosphate with water temperature and conductivity, these parameters supported the growth of *Gerris lacustris and Bulinus globosus.*

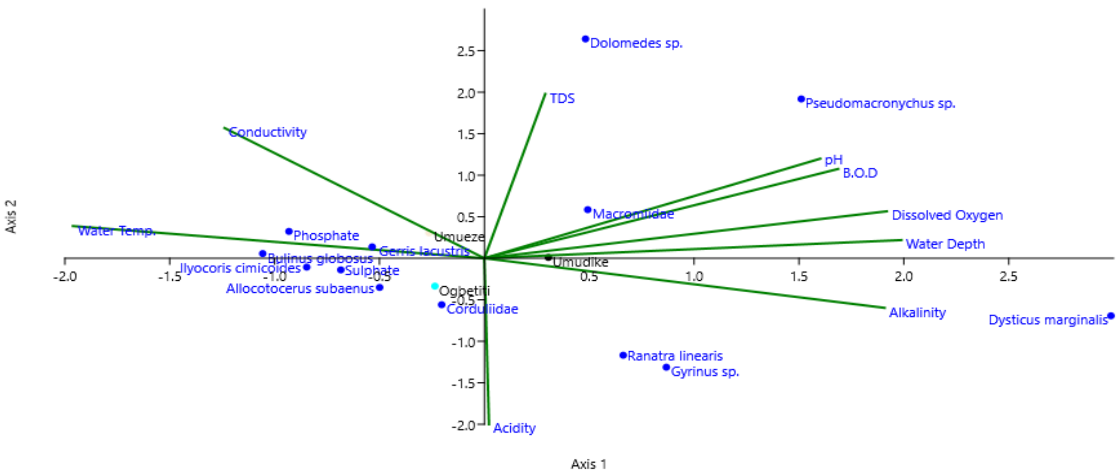

Figure 4: Triplot of first and second CCA axes of macroinvertebrates, physicochemical parameters, and the corresponding stations at Adofi River.

Macroinvertebrate Diversity Indices

The diversity of macroinvertebrates in Adofi River is shown in Table. 3. The seemly remarkable diversity was found in station 1, at 1.187, followed by station 3, 0.9275, while station 2 had the least measure of diversity, 0.7206. The evenness of distribution of organisms had a trend similar to its diversity, as the distribution was most even in station 1, followed by station 3, and station 2 was the least even station. Station 2 had the highest value for species richness, as shown by the margalef value, 0.8526. This was followed by stations 3, 0.7515, and 1, 0.6524.

Table 3: Diversity indices of macroinvertebrate communities at the sampling stations of Adofi River

	Station 1(Umudike)	Station 2 (Ogbe-etiti)	Station 3(Umueze)
Taxa_S	5	5	5
Individuals	460	109	205
Dominance_D	0.3675	0.6255	0.5417
Simpson_1-D	0.6325	0.3745	0.4583
Shannon_H	1.187	0.7206	0.9275
Evenness_e^H/S	0.6557	0.4111	0.5057
Margalef	0.6524	0.8526	0.7515

Discussion

The present study recorded a total of seven hundred and seventy-seven (777) individual organisms from 11 distinct families. This value is lower than those reported by Arimoro et al., (2007[a]) in Orogodo River, Aromoro et al., (2007[b]) in Ase River, Ikomi and Arimoro, (2014) in Ethiope River, Osimen et al., (2021) in Orijami reservoir, Niusha et al., (2014) in Jajroud river in Iran. This number is however higher than the 403 and 219 individuals reported by Iloba et al., (2018) and (2019) at Agbhara-otor and Ethiope Rivers respectively, and also Iloba and Adamu, (2020) in Anwai River. The differences in the number of macroinvertebrates reported in this study could be associated with differences in environmental conditions and the pollution status of the water body. Iloba et al., (2018) and McGoff et al., (2013) have already stated this assertion. The dominance of aquatic insects amongst the macroinvertebrate groups reported in this study has been reported by Arimoro et al., (2015) and Arimoro and Keke, (2017), who associated the dominance of specific macroinvertebrate groups with their ability to adapt to the prevailing environmental conditions of the river.

The dominance of Hemiptera in this study is similar to the reports of Iloba et al., (2019), Barman and Gupta, (2016), and Iloba and Adamu, (2020). Dolling, (1991), attributed the dominance of Hemiptera in aquatic habitats to their ability to occupy diverse niches of the ecosystem and utilize atmospheric oxygen in Oxygen deficient waters. The dominance of Hemiptera in all the sampling stations in this study, especially *Gerris lacustris* could be attributed to their ability to live in diverse habitats and stride on the water surface (Flores et al., 2016) since the oxygen levels reported in this study were high. This study identified Coleopteran, which was next to hemipteran in terms of abundance as a good indicator of pollution (Arimoro and Ikomi, (2008). Rich coleopteran assemblage, especially (gyrinus) in a water body is related to the absence of gross organic pollution (Arimoro et al., 2007), and a vast macrophyte presence (Valladares et al., (2000). This is particularly true for station I, in Adofi River, with a rich macrophyte assemblage. The presence of *Gyrinus, Dysticus,* and *Gerris lacustris* in Adofi River further indicates good water quality to support aquatic life. This position has already been reported by Arimoro et al., 2007; and Arimoro and Ikomi, 2008). The macroinvertebrate organisms reported in this study were more abundant in the dry or lower rain months than in the wet or higher rain months. This trend has been reported by Arimoro et al., (2015) and Arimoro and Ikomi, (2008). They attributed the higher number of organisms in the dry season to increased micro-habitat destruction resulting from higher surface runoffs and increased rainfall in the rainy season. In this study, higher numbers of macroinvertebrate organisms in the dry seasons are attributed to lower water volume or reduced depth, stable substrate for attachment, and greater diversity of micro-habitats for the organisms. The Odonates and Arachnida showed a similar trend in their presence in the sampling stations. They were more dominant in Station 1, followed by Stations 3 and 2. The dominance of Odonata has been reported in earlier studies by Iloba et al., (2019), and Iloba and Adamu, (2020), where they attributed the abundance of Odonata to the presence of vegetation cover. This study agrees with the authors as mentioned earlier, because, in Adofi River, the Station 1 had the highest macrophyte community covering most of the shoreline, hence providing a stable habitat for the attachment of Odonata and Arachnida. This was followed by Station 2 and Station 3, which had little vegetation. This also explains the abundance of macroinvertebrates in Station 1 compared to the two other stations since Hemiptera, Coleoptera, and Odonata have been reported to prefer habitats with a lot of vegetation present to provide habitats for attachment (Valladares et al., 2000; Iloba and Adamu, 2020; Edegbene et al., 2015, and Iloba et al., 2019). In the Mollusca order, Gastropoda showed a different trend of dominance in the Adofi River from the other organisms reported. The Gastropoda was more abundant in station 3, followed by Stations 2 and 1. Regarding dominance, they were next only to Hemiptera in stations 3 and 2. Edegbene and Omovoh, (2014), reported an abundance of Gastropods on Owan River, and Edegbene et al., (2020b) in some forested rivers in the Niger Delta area. The abundance of gastropods (Planorbidae) has been associated with sites of high nutrient concentration or highly impacted sites (HIS) (Desrosiers et al.,2019; Edegbene et al., 2020a). The CCA triplot showed that stations 3 and 2 were impacted by high nitrates, phosphates, and conductivity levels, and lower acidity, favouring the planorbidae. This is true as these stations have a massive ~~huge~~ heap of decaying cassava backs close to the river from where nutrients can be leached back into the River creating the right environment for the abundance of planorbidae.

According to Lenat *et al.,* (1980), Margalef's Index measures species richness. Numerical values of the index, lower than 3 indicate poor water quality, values of 3 indicate moderate water quality, while those greater than 3 are of excellent water quality. In Adofi River, the margalef index was all below 3 in all the sampled stations indicating that the species richness of Adofi River was poor and with poor water quality. The Shannon-Weiner index has a numerical value between 1-6, whereas values less than 1 indicate poor water quality conditions, values within the range 1-3 are said to be moderately polluted, while values between 3-6 are devoid of pollution. The values reported here indicate that Station 1 is moderately polluted, while Stations 2 and 3 are very polluted. This is true as Station I is less impacted because the macroinvertebrate organisms in this station were more abundant than the two other stations, especially with an abundance of indicators of good water quality like *Gerris lacustris, Dysticus marginalis, and Gyrinus sp.* and reduced anthropogenic activities. Stations 2 and 3, on the other hand, had an abundance of pollution-tolerant gastropod organism Planorbidae and were also exposed to intense anthropogenic activities such as cassava fermentation, leaching of decaying cassava peel deposits on the riverside, as well as the intense and continuous canoe anchorage and removal on the shorelines leading to the destruction of aquatic macrophyte in these stations. Habitat destruction/ loss of littoral macrophytes from anthropogenic activities and poor water quality conditions have earlier been reported as responsible for the low diversity of organisms in Anambra River by Odo *et al.*, (2007), Ethiope River by Iloba *et al.,* (2019) and Anwai River by Iloba and Adamu, (2020), thus aligning with this study.

Conclusion

The overall diversity indices showed a low richness and abundance of macroinvertebrates indicating poor water condition. Although there was no evidence of gross organic pollution in the river, as revealed in the CCA, especially in station 1, where DO, water depth, TDS, and BOD, influenced the abundance of *Dolomedes* sp., *Pseudomacronuchus* sp., *and the macromidae* sp, and alkalinity and acidity influenced the abundance of *Dysticus marginalis, Ranatra linearis, and Gyrinus* sp. Unstable substratum caused mainly by canoe anchorage and loss of macrophyte cover in station 2, and 3 were the leading factors, responsible for low incidence of macroinvertebrate organisms in these stations.

List of Abbreviations

Dissolved Oxygen (D.O), Biological oxygen demand (BOD), Electrical Conductivity (EC), Total dissolved solids (TDS), and Canonical Correspondence Analysis (CCA).

Author' Contribution

AON, conceived and developed the project, collected, analyzed, and interpreted data, and wrote the draft manuscript.
IRB, developed, supervised, edited and proofread the document.

Conflict of Interest

The authors declare no conflicting interest concerning the findings of this research.

Acknowledgement

The authors gratefully acknowledge the support provided by TETFUND, in the form of financial intervention to the corresponding author for his master's degree studies, as well as, the reviewers of this manuscript for their efforts in improving its overall quality.

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