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Assessing the Effect of Environmental Stressors on the Community Structure of Macroinvertebrates and Water Quality of River Ugbalo, Nigeria

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ABSTRACT

Aquatic macroinvertebrates play significant roles in the benthic zone of the aquatic ecosystem and they have different tolerance level to pollution. Globally, macroinvertebrates are usedas bioindicators in determining the ecological health and water quality status of aquatic ecosystem. Therefore, this study focused on the community structure of benthic macroinvertebrates in River Ugbalo, south-south Nigeria. Macroinvertebrates and physicochemical parameters were sampled in three marked out stations between March 2018 and February 2020. Physicochemical parameters were analyzed following standard procedures, while macroinvertebrates were collected with Kick net and Van Veen grab. Physicochemical parameters showed that the water quality of the three stations sampled were fair considering the values of pH, turbidity, sulphate, nitrate, phosphate, DO, BOD, and EC which were within the World Health Organization and Federal Environmental Protection Agency of Nigeria. Cluster analysis based on Bray- Curtis similarity showed that macroinvertebrates were clustered by stations rather than seasons. A total of 5,580 macroinvertebrates individuals were recorded showing high biodiversity in the river. Diptera was the most abundant Order with 2,488 individuals followed by Odonata with 697 individuals. The least represented Order was Lepidoptera with 13 individuals. The diversity indices showed that Margalef index (5.93), Simpson diversity (0.95), Evenness (0.63), and Shannon-Weiner index (3.30) were highest in Station 1. This research work showed that the water quality of the studied stations was fair and station 3 was the most perturbed station. We recommend the enactment and enforcement of policies that will lead to aquatic ecosystem restoration.

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INTRODUCTION

Freshwaters refer to water that are not salty such as rivers, lakes and streams. They are the most valuable natural resource on earth used by the growing human population for various purposes which include; drinking, domestic activities, fishing, transportation, industry, recreation, agriculture and energy (Olatunji & Anani, 2014). Globally and most especially in Nigeria, freshwater systems have been subjected to anthropogenic influences such as industrialization, urbanization and agricultural activities (Edegbene et al., 2021; Edegbene & Akamagwuna, 2022; Kownacki & Szarek-Gwiazda, 2022). This has affected the potability of freshwater available to the teeming population. The ecological health status of rivers is of

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great concern due to the fact that in its non-potable form it leads to reduction in biodiversity, deteriorated water quality and death of organisms that depend on water for survival (Araujo et al., 2018). Furthermore, introduction of exotic species and dredging, adversely affect freshwater ecosystems and their inhabitant's biodiversity (Edegbene et al., 2019a). The exposure of rivers to anthropogenic and other pressures ultimately reduce the integrity of rivers (Erasmus et al., 2021). The adverse effects of these pressures on the riverine ecosystem is colossal, hence there is need for river managers to assess the water quality of rivers to ascertain their potability. In assessing the water quality of rivers, physicochemical variables have been employed by several authors (Emeribe et al., 2016; Iyama et al., 2019). The variables are good indicators of riverine health, and the variables include electrical conductivity, sodium, sulphates, nitrates, phosphates, nutrients, dissolved oxygen, biological oxygen demand and heavy metals (Iyama et al., 2019; Odigie & Olomukoro, 2020; Edegbene et al., 2021; Keke et al., 2021; Ogidiaka et al., 2022; Edegbene et al., 2022). The physicochemistry and biochemical assessment of rivers reflects the water quality only at the time of sampling and not the functional and structural properties of the river which biological assessment shows (Edegbene et al., 2021), hence the need to conduct both assessments to have a wholistic view of the health status of rivers. Many aquatic biota such as planktons (Zahraddeen, 2020; Ramezanpour, 2014) , macrophytes (Abebe et al., 2021), bacteria (Abera et al., 2011; Olatunji et al., 2019) , macroinvertebrates (Agboola et al., 2020; Edegbene et al., 2021; Garba et al., 2022) and fish (Ogidiaka et al., 2013; Odige et al., 2016) have been used to determine the ecological health of freshwater bodies.

For instance, Agboola et al. (2020) stated that aquatic benthic macroinvertebrates are the most responsive to aquatic stressors. Benthic aquatic organisms are ubiquitous and known to exhibit different tolerance to different levels of pollution. Therefore their high level of diversity show dependable signs concerning the ecological health status and environmental degradation of the surrounding aquatic environment. Benthic macroinvertebrates have short life span, sessile, easy to collect, sort and identify (Arimoro & Ikomi, 2009; Olomukoro & Dirisu, 2014; Odigie, 2019). Furthermore, the structural assemblage of aquatic macroinvertebrates reflects the quality of the aquatic environment; their use as bioindicators in determining the ecological health status of aquatic environment has been explored globally (Arimoro et al., 2015; Aghajari et al., 2021; Kownacki & Szarek-Gwiazda, 2022) but literature on the studies of the structural assemblages of macroinvertebrates in Nigeria are still building up. Hence, the present study was aimed to determine the ecological health and water quality of River Ugbalo.

MATERIALS AND METHODS

River Ugbalo is located between the interception of Latitude 6° 54' 3'' N and Longitude 6° 17' 7''E of the equator. The river is located in Ugbalo town in Esan Central Local Government Area (L.G.A.) of Edo State south-south, Nigeria. The river flows through Ibore, Atuagbo to Ugboha towns, all in Esan Central L.G. A. The study area is within the tropical rain forest belt of Nigeria, characterized with heavy rainfall during the wet season, and a relatively shorter dry season. The wet season is between April to October while the dry season is between November and March (Edegbene et al. 2021; Edegbene, 2021). The mean annual temperature is 37°C (Osuinde *et al*., 2002) and a mean annual rainfall of 1300- 2500mm (Edegbene, 2021). Dominant plants and macrophytes around River Ugbalo include: *Achyranthus aspera, Acroceras zizanoides, Combretum racemosum, Colocasia esculenta, Alchornea cordifolia, Chromolaena adorate,Cercestris afzelii, Bambusa vulgaris, Baphia nitida* and *Zea mays*.

In this study, we marked out three stations along the course of River Ugbalo considering the level of accessibility, canopy cover, impact of human activities and logistics (Figure 1).

Station 1 is the upstream section of River Ugbalo, it is close to the river source. The streambed is dominated withloamy and clayey sediments. Forest trees formed a close canopy around the

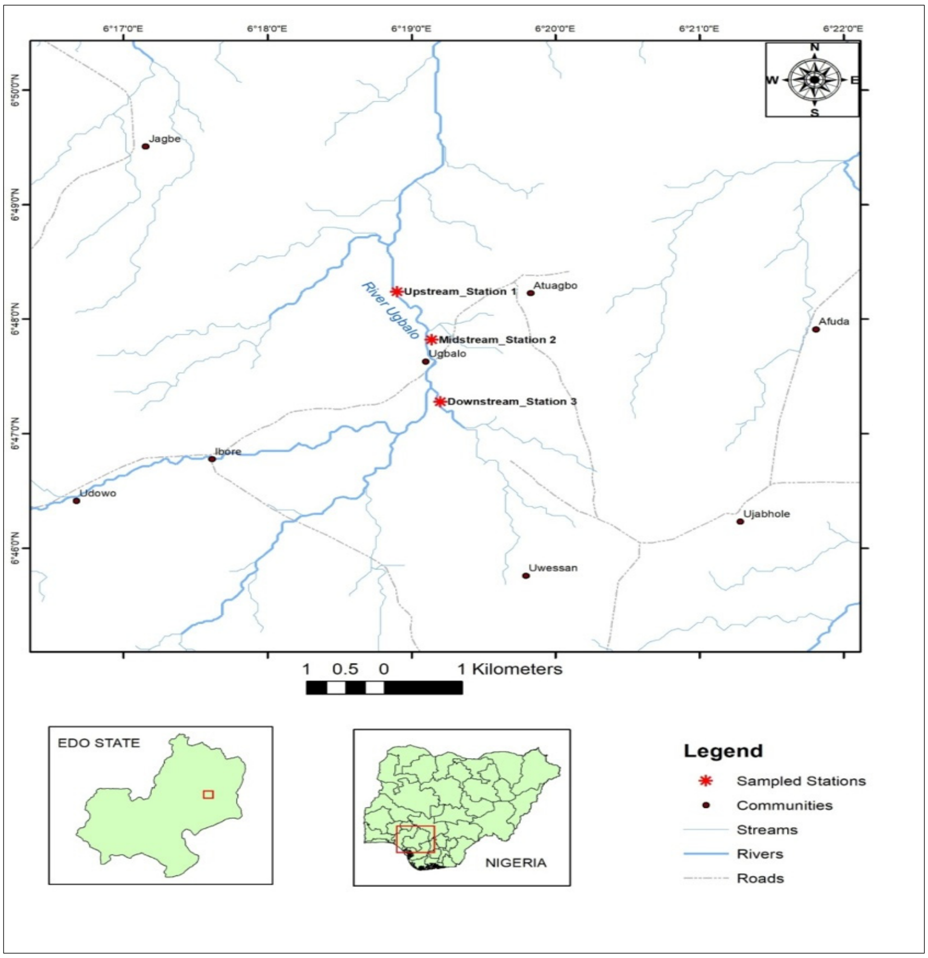

Fig. 1. Map of the Study area showing the sampling stations of River Ugbalo (Maps of Nigeria and Edo State inserted)

river in this station. The station had little anthropogenic activities such as subsistence farming. Storm water return-flow is the major source of pollution in this station (Figure 1).

Station 2 is 1.7km from Station 1. The station is mainly used for washing and bathing. The streambed in this study is mainly loamy and silty. High anthropogenic activities characterized the station and they include–farming, washing, bathing, swimming, offering site for sacrifices to water deity/religious exercise and source of potable drinking water and other domestic purposes for the villagers (Figure 1).

Station 3 is 1.4km away from Station 2. The streambed is mainly clayey and loamy. The station is subjected to high anthropogenic activities which include: farming, logging, animal grazing and irrigation. storm water return-flow from adjacent communities and farmland contribute the major source of pollution in this station (Figure 1).

Sampling expedition was carried out monthly between the hours of 7:00am and 10:00am for a period of 24 months spanning from March 2018 to February 2020.

Physicochemical parameters analyzed during the study period include: air and water temperature, water depth, flow velocity, transparency, pH, electrical conductivity (EC), turbidity, chloride, nitrate, phosphate, sulphate, dissolved oxygen (DO) and biochemical oxygen demand (BOD). Air and water temperatures were measured with a mercury thermometer on site in °C. A standardized ruler calibrated in centimetre was used to calculate the water depth and later converted to meters after the reading. A floated ball was timed thrice to get the average flow velocity as earlier employed by Njosi, (2010) , and the flow velocity was recorded in meter per seconds (m/s). pH meter (model: HANNA HI 9828) and secchi disc were used to measure pH and transparency, respectively. A conductivity meter (model: DDSJ-308A) was used to measure electrical conductivity measured in µS/cm. A turbidity meter (model: WGZ-B) was used to measure turbidity meter in nephelometric turbidity unit (NTU). Phosphate, nitrates, sulphates, Chloride, DO and BOD were determined using APHA (1998) standard methods.

Alongside, physicochemical variables sampling and analysis, macroinvertebrates were collected from the bank root using Kick sampling method with the aid of a modified kick net of 500µm mesh size propelled against the water current in each station. Sampling at each bank root was done for three minutes. Van-Veen grab made by Hydrobios was used to collect samples from the depositional biotope. Three hauls were pulled to collect the depositional macroinvertebrates which were later sieved and stored in a covered plastic container fixed in 10% formalin before transporting to the laboratory for further analysis. Samples collected from the two biotopes – bank root and depositional of each station were added together to form a composite sample. The samples were sorted, identified taxonomically to the lowest level possible, most especially genus and counted finally in the laboratory using white enamel tray, forceps, dissecting microscope and identification keys (Mellanby, 1975; Arimoro and James, 2008; Tagliapetra and Sigovini, 2010).

The mean, standard deviation, minimum and maximum value of all the physicochemical parameters were calculated using SPSS statistical software version 16.0 (SPSS Inc, 2007). Analysis of variance (ANOVA) was calculated in order to clarify the significant differences within means of the physicochemical parameters in the three stations sampled. Turkey's post hoc HSD test was conducted thereafter for means of physicochemical parameters that showed significant differences. Simpson diversity, Margalef index, Shannon-Weiner diversity and Evenness index were calculated using Diversity function on Paleontological Statistical Package (PAST) version 3.01. (Hammer *et al*., 2001). Cluster analysis based on Bray–Curtis similarity index was done to establish whether macroinvertebrate community composition was structured either by seasonal differences or station-by-station differences using PAST version 3.01 (Hammer *et al*., 2001).

Principal Component Analysis (PCA) was used to correlate the original 14 physicochemical parameters with the three sampled stations in a bid to ascertain the water quality of the river.

The Canonical Correspondence Analysis (CCA) was used to show the species correlation coefficients explained by the variation in the individuals and physicochemical parameters. A monte Carlo permutation test with 199 permutations was used to determine the significance of the first three canonical axes of the CCA (Jckel, 1986).

RESULTS AND DISCUSSION

Physicochemical parameters

The mean, standard deviation and level of significance difference of the physicochemical parameters among the stations in River Ugbalo are shown in Table 1. The physicochemical parameters showed no significant differences among the stations sampled (P>0.05).

Relationship between physicochemical parameters and stations sampled

Correlation of physicochemical parameters with the sampled stations in the 24 months sampling period using PCA explained that component 1 had a percentage variance of 67.9% of the entire PCA value with an Eigenvalue of 9.5 while Component 2 of the PCA explained a percentage variance of 32.1% of the entire PCA value with an Eigenvalue of 4.5. Physicochemical parameters such as phosphate, transparency, sulphate, water depth, nitrate, flow velocity, chloride, BOD, Chloride, DO and pH are positioned on component 1 of the

Table 1. Summary of Physicochemical parameters at River Ugbalo study stations, March, 2018 to February, 2020.

Parameters	Station	Mean	Std deviation	Minimum	maximum	F value	FEPA	WHO
	ST1	29.66a	1.06	27.40	31.60			
WATER TEMPERATURES (°C)	ST2	30.60a	1.04	28.10	32.50	5.42	40	
	ST3	29.6b	1.37	27.00	31.90			
	ST1	31.6a	1.11	29.40	33.70			
AIR TEMPERATURE (°C)	ST2	32.9b	1.04	31.00	34.70	8.40	40	
	ST3	32.4a	1.15	30.10	34.20			
	ST1	32.96a	10.25	12.00	49.00			
FLOW VELOCITY (cm/s)	ST2	38.92a	9.96	18.00	55.00			
	ST3	51.17b	13.22	21.00	77.00			
	ST1	11.25a	2.35	6	16			
TRANSPARENCY (cm)	ST2	9.5b	1.72	5	12			
	ST3	13.92c	1.95	9	16			
	ST1	0.42a	0.12	0.18	0.60			
WATER DEPTH (m)	ST2	0.50a	0.10	0.27	0.66			
	ST3	0.57a	0.13	0.31	0.73			
	ST1	13.78a	0.86	12.40	15.40			
CHLORIDE (m/gl)	ST2	13.42ab	0.88	12.00	15.10			
	ST3	14.09b	0.96	12.40	15.90			
	ST1	0.31a	2.32	0.25	0.37			
NITRATE (m/gl)	ST2	0.64b	2.09	0.49	0.80	59.47		
	ST3	2.51c	2.09	2.27	2.63			
	ST1	0.03a	0.11	0.02	0.50			
PHOSPHATE (m/gl)	ST2	0.17ab	0.38	0.03	0.85	3.13	5.0	
	ST3	0.21b	0.38	0.06	1.00			
	ST1	6.71a	3.30	3	16			
SULPHATE (m/gl)	ST2	9.04b	3.85	2	19	33.75	200-400	250
	ST3	15.25c	4.00	8	22			
	ST1	39.02a	2.30	35.00	42.00			
ALKALINITY (m/gl)	ST2	43.60b	2.83	39.00	48.50	43.47		600
	ST3	45.27c	2.00	41.00	49.00			
	ST1	1.50a	0.24	1.01	1.90			
BIOLOGICAL OXYGEN DEMAND (m/gl)	ST2	1.90b	0.44	1.46	2.95	34.08	10.00	5.00
	ST3	4.28c	0.48	3.27	4.95			
	ST1	7.15a	1.43	4.50	8.90			
DISSOLVED OXYGEN (m/gl)	ST2	6.72ab	1.23	4.50	8.70	2.62	5.00	5.00
	ST3	6.30b	1.16	4.50	8.50			
	ST1	7.29a	0.68	6.50	8.50			
pH	ST2	6.63a	0.71	5.50	7.80	10.87	6.00-9.00	6.50-8.50
	ST3	6.38b	0.72	5.40	7.50			
	ST1	5.58a	1.69	4.30	9.10			
CONDUCTIVITY (µS/cm)	ST2	8.09a	2.11	4.50	11.30	3.94	-	600
	ST3	6.88b	1.67	4.50	9.80			

Different superscript letters in a parameter show significant differences ($P<0.05$) indicated by Tukey Honest significant difference tests.
*None of the F value is significant.

PCA (Figure 2). Conductivity, alkaline, air temperature and water temperature were positioned on component 2 of the PCA (Figure 2). Conductivity, air temperature and water temperature were strongly positively correlated with Station 2 (Figure 2). Physicochemical parameters such as biological oxygen demand, sulphate, flow velocity, and water depth were strongly positively correlated with Station 3 while dissolved oxygen and pH were positively correlated with Station 1 (Figure 2).

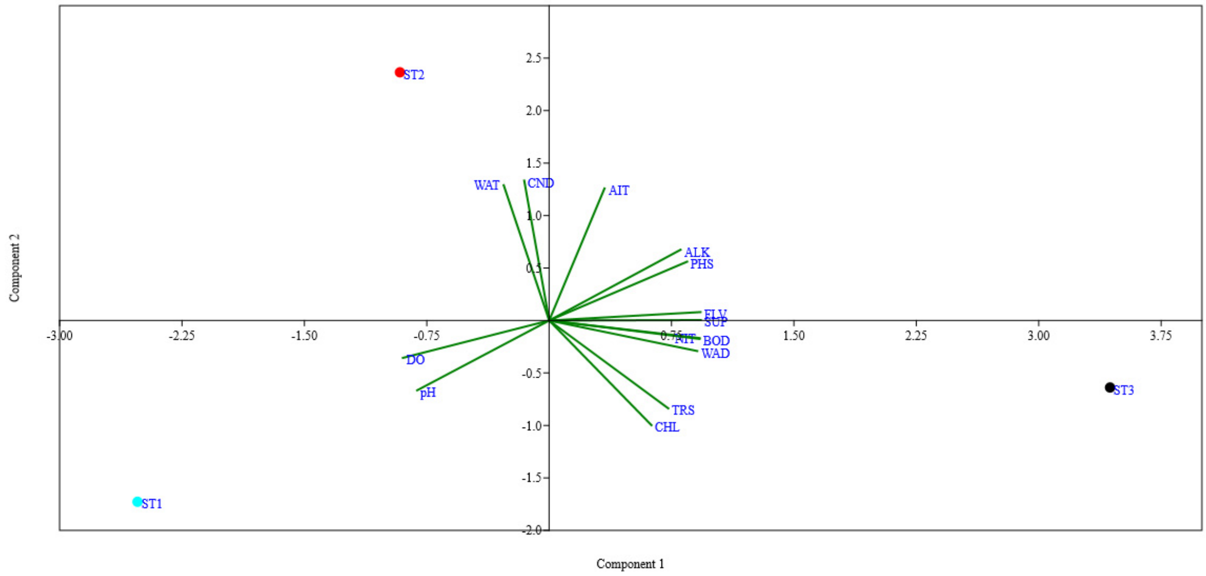

Fig. 2. Principal Component Analysis of River Ugbalo during the study period

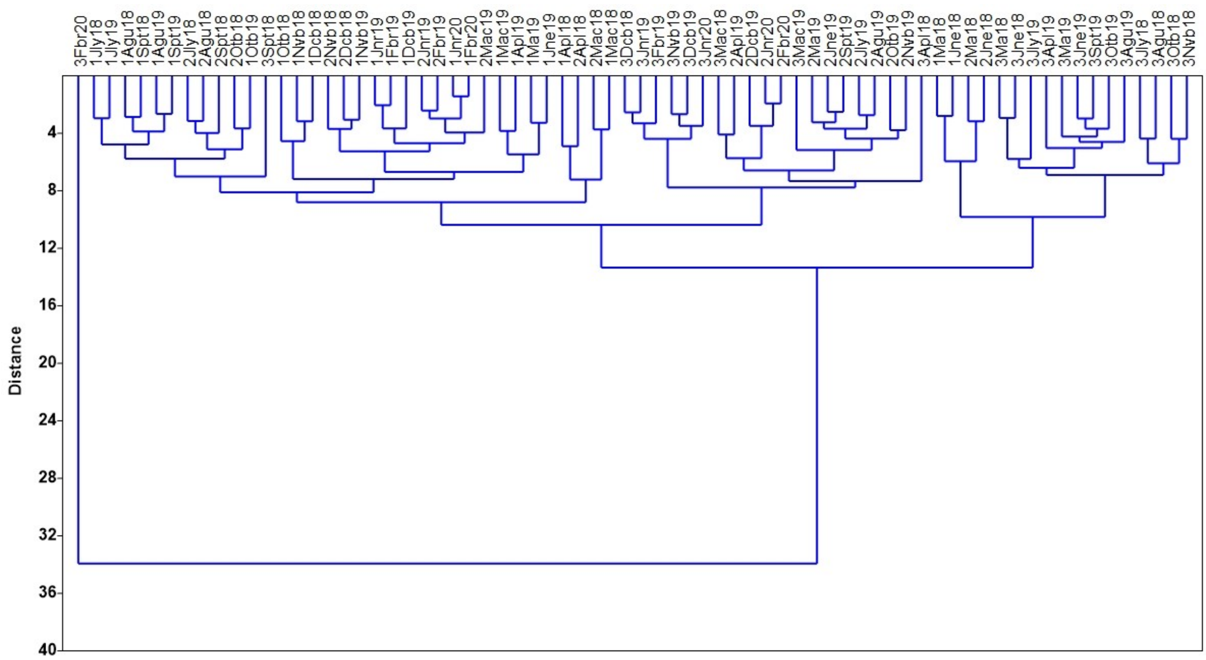

Fig. 3. Cluster analysis of the physicochemical parameters in River Ugbalo during the study period.

Cluster Analysis of the physicochemical parameters in River Ugbalo

The cluster analysis based on Euclidean similarity showed that the physicochemical parameters were clustered by stations rather than seasons (Figure 3).

Benthic macroinvertebrates community structure

A total of 5,580 macroinvertebrate individuals, comprising of 12 orders 33 families and 47 taxa were recorded in this study (Table 2). The number of taxa and individuals recorded were, Station 1: 41 taxa and 1,966 individuals, Station 2: 33 taxa and 1,717 individual and Station 3:

Table 2. Abundance of macroinvertebrates in relation to the study stations

ORDER	FAMILY	TAXON	STATION		
			ST1	ST2	ST3
ODONATA	Libellulidae	*Libellulida quadrimacolata*	122	31	10
		Pachydiplax sp.	44	14	4
		Sympetrum sp.	8	0	0
	Gomphidae	*Octogomphux* sp.	46	28	12
		Hainus sp.	28	21	10
	Aeschnidae	*Aeschna umbrosa*	148	29	5
		Anax sp.	47	16	2
	Coenagrionidae	*Coenagrion* sp.	14	6	5
		Ischnura sp.	1	0	0
	Calopterygidae	*Calopteris maculate*	25	4	1
	Cordulidae	*Cordulia* sp.	7	5	2
		Epitheca cynosura	2	0	0
COLEOPTERA	Hydrophilidae	*Hydrophillus* sp.	34	20	8
		Helochares sp.	7	4	1
	Dystiscidae	*Cybister* sp.	108	64	16
		Philodyter sp.	40	16	3
		Lybrister sp.	75	15	3
	Elimidae	*Heterlimius*	36	26	2
HEMIPTERA	Nepidae	*Nepa* sp.	65	25	11
	Gerridae	*Gerrid* sp.	42	36	11
	Veliidae	*Microvelia* sp.	11	7	3
	Pleodae	*Pleo* sp.	47	30	0
DIPTERA	Chironomidae	*Chironumus fractilobus*	198	208	325
		Chironumus transvaalensis	96	288	443
		PseudoChironomus sp.	13	34	38
		Pentaneura sp.	51	236	482
	Tipulidae	*Tipula* sp.	7	20	24
	Simulidae	*Simulium* sp.	5	14	6
EPHEMIROPTERA	Baetidae	*Baetis tricaudatus*	53	30	3
		Pseudocloeon sp.	132	18	73
	Oligoneuridae	*Elassoneuria* sp.	6	0	0
	Heptageniidae	*Afronurus* sp.	45	37	48
PLECOTERA	Perlidae	*Neopeta* sp.	108	28	21
TRICHOPTERA	Philopotamidae	*Aethaloptera* sp.	28	9	0

Continued Table 2. Abundance of macroinvertebrates in relation to the study stations

ORDER	FAMILY	TAXON	STATION		
			ST1	ST2	ST3
	Hydropsychidae	*Hydropsyche* sp.	36	13	3
	Ecnomidae	*Parecnomina* sp.	14	4	2
LEPIDOPTERA	Paralidae	*Nymphula stratiotata*	13	0	0
DECAPODA	Atyidae	*Caridina africana*	13	110	32
		Euryrhynchina sp.	10	66	48
	Potamonautidae	*Potamonautes* sp.	32	7	11
	Palaemonidae	*Macrobrachium* sp.	4	12	18
AMPHIPODA	Amphipoda	*Gammarus* sp.	55	22	10
OLIGOCHAETA	Lumbricidae	*Lumbricus* sp.	68	111	109
	Naididae	*Dera* sp.	12	12	54
		Nais sp.	0	15	15
	Tubificidae	*Tubifex tubifex*	8	12	22
ARACHNIDA	Agronectidae	*Agronecta* sp.	2	14	1

40 taxa and 1,897 individuals. The abundance of macroinvertebrates was significantly different ($P < 0.05$) among the sampled stations.

Monthly and Seasonal Variations of Macroinvertebrates

The monthly and seasonal variation of the macroinvertebrates collected is shown in Figure 4. More macroinvertebrates were collected during the wet season – 4,719 (84.6%) than the dry season - 861 (15.4%). Station 1 had the highest number of macroinvertebrates - 1966 (35.2%), while Station 2 had the least – 1717 (30.8%).

Cluster Analysis

The cluster analysis based on Bray- Curtis similarity showed that macroinvertebrates were clustered by stations rather than seasons (Figure 5).

Faunal Diversity and Dominance

The faunal diversity and dominance indices for the 3 stations in River Ugbalo are in Table 3.

Relationship between physicochemical parameters and macroinvertebrates:Canonical Correspondence Analysis

The CCA triplot conducted revealed that Axis 1 accounted for 89.53% of the entire CCA variance with an eigenvalue of 0.25818, and Axis 2 accounted for 10.47% of the entire CCA variance with an eigen value of 0.0302. Monte Carlo permutation test at 999 permutation showed that there was no significant difference in terms of the relationship among the stations, physicochemical parameters and the macroinvertebrates ($p > 0.05$) in both axes. Dissolved oxygen and pH were positively correlated with the following families - Elimidae, Perlidae, Calopterygidae, Amphipodae, Hydrophilidae, Philopotamidae, Gomphidae, Veliidae, Nepidae and Aeschnidae in Station 1. Conductivity, air temperature and water temperature were positively correlated with Atyidae, Simulidae and Agronectidae in Station 2. Water depth, flow velocity, biological oxygen demand, chloride, nitrate, sulphate, and transparency were

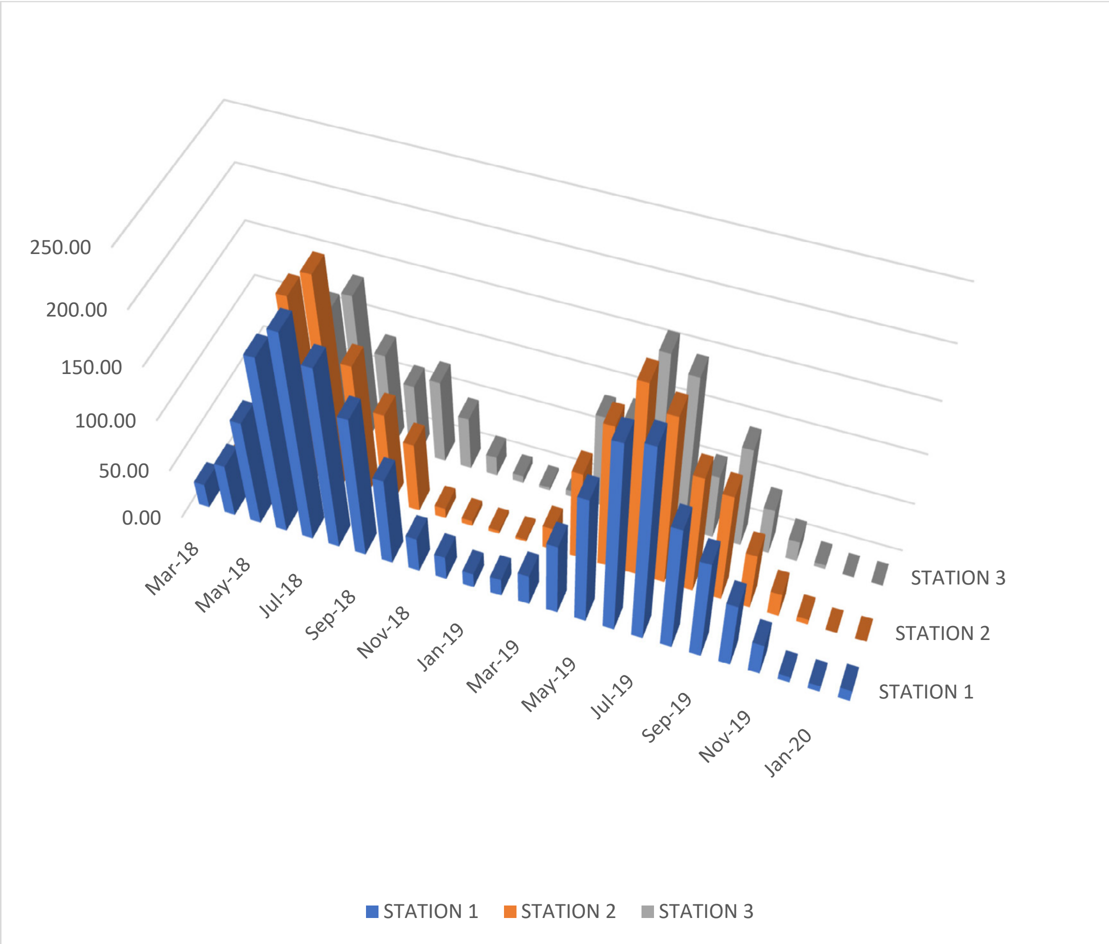

Fig 4. Spatial and Temporal variation in composition of macroinvertebrates in the sampled stations of River Ugbalo, Edo State, Nigeria, during the study period.

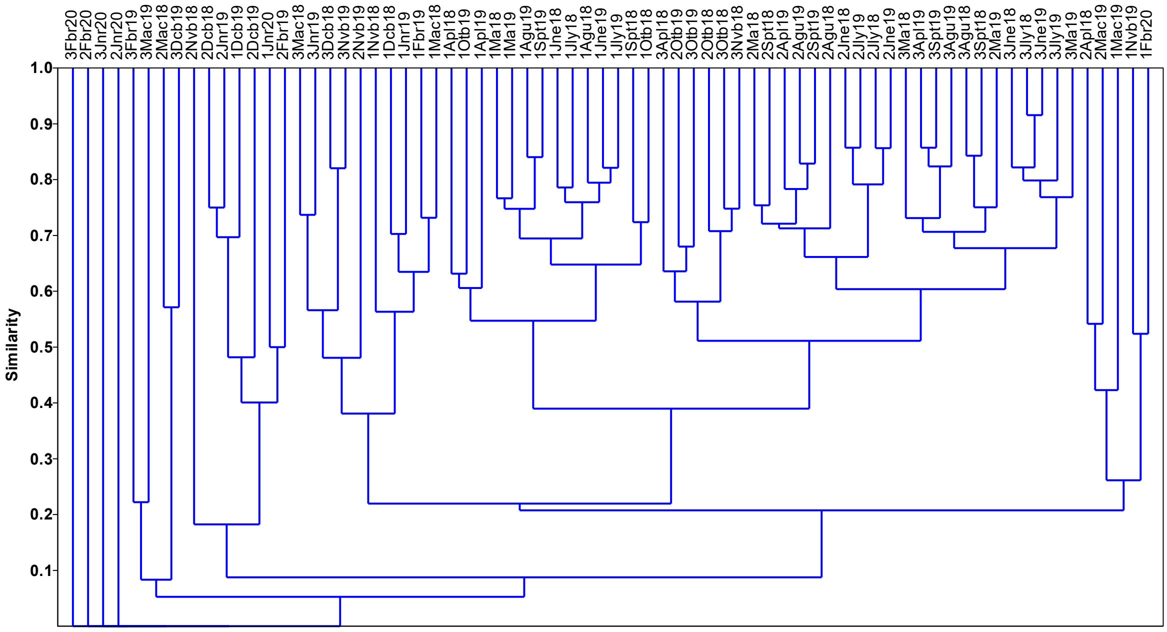

Fig. 5. Cluster analysis of the macroinvertebrates in River Ugbalo during the study period.

Faunal Diversity and Dominance

Table 3. Diversity of benthic macroinvertebrates in the study stations of River Ugbalo during the study period.

	ST1	ST2	ST3
Taxa_S	46	42	40
Individuals	1966	1717	1897
Simpson_1-D	0.9557	0.9221	0.8772
Shannon_H	3.377	3.054	2.598
Evenness_e^H/S	0.6365	0.5047	0.3361
Margalef	5.934	5.505	5.369

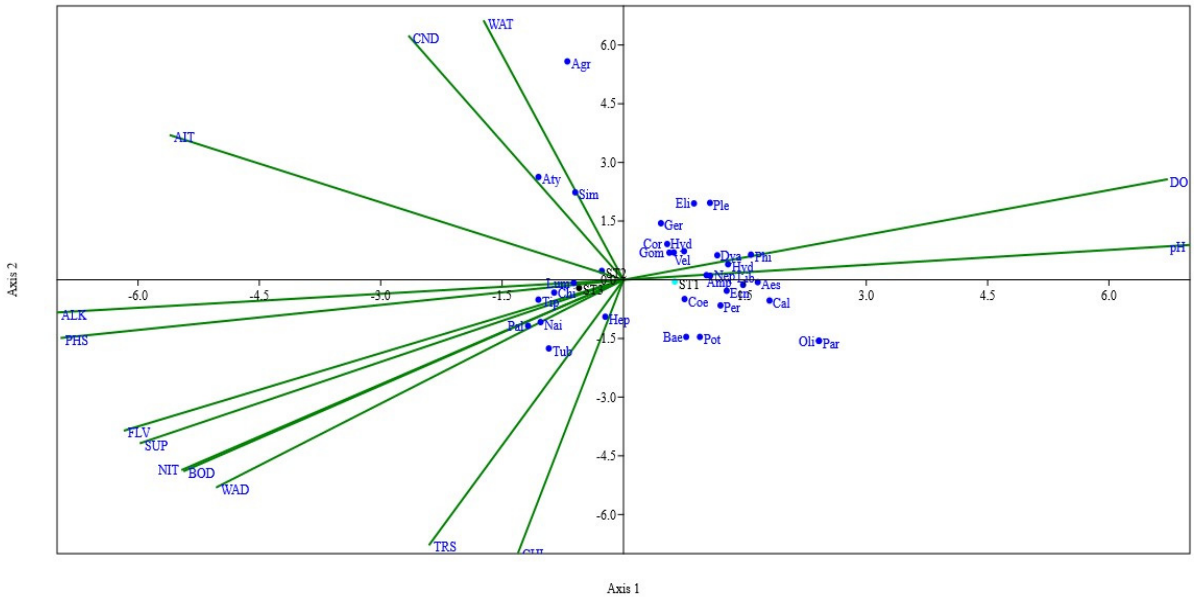

Fig. 6. CCA ordination diagram for stations and environmental relationships for macroinvertebrates families in Ugbalo River, Edo State, Nigeria, during the study period.

negatively correlated with Chironomidae, Palaemonidae, Tipulidae, Naididae and Tubificidae families in station 3 (Figure 6).

Generally, the WHO and FEPA standard limits showed the physicochemical results of River Ugbalo had relatively fair environmental quality, the stations were not significantly polluted along anthropogenic stress gradient. The results collaborate with studies within the Niger Delta region of Nigeria (Arimoro et al., 2014; Odigie & Olomukoro, 2020; Edegbene et al. 2022) where they reported similar high values of DO and relatively low values of BOD_5 which they attributed to high organic matter input from the riparian zones of the rivers they studied. Phosphate, EC, Nitrate, Sulphate and BOD were within the recommended standard of WHO (WHO, 2011) and the permissible limit of Nigeria Water Quality standard for inland surface water. Anthropogenic activities such as indiscriminate defecation, use of fertilizer/pesticide, industrialization, urbanization, dredging, over dependent on the river for household use, polluted effluents and bunkering are causes of river systems degradation in Sub Saharan Africa (Olatunji et al., 2019). These activities with the exception of industrialization, urbanization and bunkering were vividly present in the catchments of River Ugbalo, confirming the reason for the high values of some pollution indicating physicochemical parameters. Odigie (2014) noted that the presence of market and industrial establishments aggravated the level of environmental stress in most of the stations they sampled in rivers located in the southern part of Nigeria. The level of physicochemical parameters determines the pattern/assemblage of benthic macroinvertebrates in any aquatic ecosystem (Edegbene et al., 2021; Arimoro and Keke, 2021).

The spatio-temporal analysis showed more macrobenthos were collected during the wet season (4,719) than the dry season (861) similar to the results of Edegbene & Arimoro (2012) in Owan River, Nigeria and Abebe et al., (2009) in Borkena River, Ethiopia. This might be because of erosion and flood which dispatch some macroinvertebrates from different locations to the bank root area. This result differs from that of Arimoro et al., (2015) in which the abundance was more in the dry season than wet season because of the unstable substrate originating from stormy waves from run off. Station 1 had the highest number of macroinvertebrates – 1,966, while Station 2 had the least – 1,717.

The cluster analysis based on Bray- Curtis similarity showed that macroinvertebrates were clustered by stations rather than seasons most likely because of the different anthropogenic stressors and substrate in each station. A similar result was recorded by Awomeso et al., (2020) in the groundwater at the basement rocks of Osun State, Nigeria.

A total of 47 taxa made up of 5,580 macroinvertebrates individuals were collected during this study; this was likely because of the preponderance of Chironomidae which can tolerate varied environmental variable differentiation. This result is similar to the results of earlier studies in different regions in Nigeria (e.g., Omovoh et al., 2022; Fekadu et al., 2022). Further, Ibemenuga & Inyang (2006) recorded 50 taxa in Ogbei stream in Anambra State, Nigeria; Fekadu et al., (2022) recorded 68 taxa of macroinvertebrates in River Kipsinende in Kenya. They attributed the wide assemblage of macroinvertebrates to substrate composition, food availability and excellent water quality.

Ephemeroptera, Plecoptera and Tricoptera have been used globally to indicate good ecological health integrity of freshwater systems, because of their sensitivity to environmental stressors (Edegbene & Arimoro, 2012). The significantly high abundance of the pollution sensitive taxa – Ephemeroptera, Plecoptera and Tricoptera in Station 1 (21.5%) compared to the other stations, portrayed the station as having better water quality. On the other hand, Chironomidae and Oligochaetae have been used globally to indicate poor health water integrity because of their tolerance to environmental stressors hence their reliable use as bioindicators of deteriorating water (Arimoro & Ikomi, 2009; Edegbene et al., 2019b). The pollution tolerant taxa – Diptera and Oligochaeta, were significantly most abundant in Station 3 (51.9%) portraying the station as the most polluted compared to the other stations since they were globally associated with polluted water. Edegbene *et al.,* (2021) had earlier reported that pollution sensitive taxa – Ephemeroptera, Plecoptera and Tricoptera were significantly more in the upstream than the midstream and downstream, while the pollution tolerant taxa – Diptera and Oligochaeta, were significantly more abundant in the downstream compared to the upstream and midstream of the riverine systems they studied in the Niger Delta in Nigeria. They attributed this to more anthropogenic activities in the downstream compared to the upstream. Odigie & Osimen, (2018); Olatunji et al., (2029) and Garba et al., (2022) stipulated that aquatic ecosystem respond in a spatial scale to environmental stressors like industrialization, urbanization, agricultural activities and excessive use of water resources due to overpopulation

The diversity indices also portray the river water in the studied stations as being unperturbed. Lenat et al., (1980) proclaimed that the Margalef index value greater than 3 shows the water health status is clean while a value less than 1 shows it is polluted; the Margalef index (taxa richness) for the three stations were greater than 5. Station 1 had the highest value (5.934) while station 3 had the least value (5.369); confirming the deteriorating condition of Station 3.

The present study showed high abundance and diversity of macroinvertebrates in all the sampled stations with Station 1 having the highest abundance, diversity and evenness and Station 3 the least. This conforms to the works of Erasmus et al., (2021) and Tampo et al., (2021) that the upstream had more diversity and evenness of macroinvertebrates than the downstream.

This can be explained with the presence of less anthropogenic activities in Station 1 compared to Station 3. It is noteworthy that the movement downstream from Station 1 to 3 showed the different biodiversity indices decreased with the significant reduction of the pollution sensitive taxa such as *Baetis tricaudatus, Neopeta* sp. and *Hydropsyche* sp. and increase of pollution tolerant taxa such as *Dera* sp., *Tubifex tubifex* and Chironomidae. The percentage composition of the pollution sensitive orders - Ephemeroptera, Plecoptera and Trichoptera decreased significantly from Station 1 (21.5%) downstream to Station 3 (10.5%) with decreasing DO while the percentage composition of the pollution tolerant orders - Chironomidae and Oligochatae in Station 1 (22.7%) increased significantly (52.2.%) in Station 3 with increasing nutrients. These could be because of run off from agricultural/forestry activities, animal grazing and decomposing plants/food sacrifices. Odigie, (2019) and Erasmus et al., (2021) reported the dominance of Oligochaetae and Chironomidae in River Obueniyomo while and River Hex, respectively. Further. Edegbene et al., (2021) highlighted the affinity of Oligochaetae and Chironomidae to low oxygen and enrichment of nutrients in River Kafin Hausa in addition to the affinity of Ephemeroptera, Plecoptera and Trichoptera to DO and pH.

Based on nutrient enrichment, the sensitivity values of the macroinvertebrates showed that the pollution tolerant taxa were the predominant taxa in all the stations in the course of the study. The predominant orders observed altogether in all the stations were Aeschnidae, Baetidae, Dysticidae, Atyidae and Chironomidae. These orders are highly pollution sensitive except Atyidae and Chironomidae (Awrahman et al., 2016; Costas et al., 2018).

The PCA and CCA showed EC, the nutrients, sulphate and phosphate correlated with the presence of the orders Chironomidae and Oligochaete while pH and DO correlated with the presence of the Ephemeroptera, Plecoptera and Trichoptera. This confirms the tolerance of Chironomidae and Oligochaete to pollution. This observation is similar to the results of Keke et al. (2021) where they portrayed the selective sensitivity of different orders/families of macroinvertebrates to the physicochemical parameters of River Siluko, Edo State, Nigeria.

CONCLUSION

The global aquatic ecosystem integrity is adversely affected by anthropogenic activities; rivers in Esanland are not excluded and not well explored. This study portrays a fair water quality in the three sampled stations of River Ugbalo with Station 1 being less perturbed compared to the remaining two stations . The physicochemical parameters results showed most of the major parameters were within the WHO and FEPA acceptable limit. The PCA reduced the 14 physicochemical parameters studied to 5 significant principal components that structure the ecosystem, namely conductivity, sulphate, phosphate, DO and BOD. The concentration of nutrients along the river course/stations reflect increased pollution with the presence of foremost anthropogenic stressors. Anthropogenic stressors such as dung depositions, agricultural runoffs, plant and food sacrifice decay, deforestation, bathing and washing led to high nutrient concentration and low pH of Station 3 leading to the preponderant of pollution tolerant taxa in this station. Despite the fact that most of the physicochemical parameters were within WHO and FEPA standard limits with a rich structural assemblage of macroinvertebrates, the preponderant of pollution tolerant taxa in Station 3 is a red flag signifying deterioration which if unhindered will eventually jeopardize the ecological integrity of this river. It is recommended that a more detailed research be carried out covering the whole stretch of River Ugbalo to further confirm the result of the present study. In addition to determining the actual level of pollution in River Ugbalo as a result of various anthropogenic stress in the river catchments, we recommend the development of biotic indexes recommend the development of biotic indexes for rivers within the south-south region which will enhance the rapid bioassessment of the ecological health of rivers as against the mere assessment of ecological health using physicochemistry and assemblage structure of macroinvertebrates employed in the present study. The influence of overexploitation of macroinvertebrates by man on the evolutionary changes in macroinvertebrates should be studied as well. In addition, it is recommended that the conservation and genetic diversity of macroinvertebrates should be added to the United Nation's biodiversity targets. Promulgation and enforcement of Governmental policies, community enlightenment and participation are paramount for effective aquatic ecosystem restoration that will make River Ugbalo to be classified indeed as an epitome of the most valuable natural resource in the universe - FRESHWATER.

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CONFLICT OF INTEREST

The authors declare that there is no any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and /or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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