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Macroinvertebrate structure and diversity in nutrient-rich ephemeral pools in Delta State University, Abraka, Nigeria

Kate Isioma Iloba*

Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria

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Abstract

This study used the Macroinvertebrate fauna to assess the ecological status and uniqueness of temporary, ephemeral pools in Delta state university, Abraka from 26th to 28th of October 2018, using standard methods. Among the studied environmental parameters, nitrate alone was significantly different among the pools ($p<0.05$). The pools macroinvertebrates handicapped supported seventeen taxa only from sixteen (16) families with a total of 460 individuals belonging to Odonata (28.91%) Oligochaeta (26.09%), Diptera (24.57%) Hemiptera(12.39),Gastropoda (4.35%), Coleoptera(3.48%), and Arachnida (0.22%) in order of dominance. The pools macroinvertebrates dominated by the group odonatan of the class Insecta. (*Lumbricus terrestis Linnaeus* 1758) (pollution-sensitive) found dead in the pools, low diversity indices(total taxa, Margalef index, dominance, and the Shannon diversity index), the occurrence and predominant of chironomus larvae (pollution-resistant worms) at the species level (24.57%) sign deteriorated water quality. The high number of resistant blood worms, low numbers of Gyrinus and Coleoptera is suggestive that they are suitable biological indicators of high concentration of the studied parameters in the pools and thus can be bioindicators of impaired water bodies.

* **Corresponding Author:** Kate Isioma Iloba ✉ kisyiloba@gmail.com

Introduction

Macroinvertebrate fauna structure and diversity is a vital tool assembly in assessing the ecological status of aquatic ecosystems (Sanz-Lazaro and Marin, 2011). Temporal water bodies are essential aquatic ecosystems for ecological studies due to their ecological merits or benefits. Not the less, these valuable water bodies are rarely studied despite their ecological information. The inordinate study of temporal pools has been attributed to the size and their ephemeral nature and looking seemingly unimportant. There are little or no pool ecological studies in Nigeria (Arimoro *et al.,* 2008; Iloba *et al.*, 2018). They (temporary pools) strained by diverse human and environmental factors impacting on their uniqueness.

Notwithstanding, temporal water bodies are complex and repositories for unique biotas, particularly the non-mobile macroinvertebrates (Epele *et al.*, 2016). These macro-biotas associated with small water bodies are unique, diverse, and a roster/ handbook of rare species of great hydrobiological significance (Brown *et al.*, 2016). The presence and absence of macroinvertebrate species at any given period indicate the average or/and intense conditions prevalent in the aquatic environment during the specific period (Parmar *et al.*, 2016). Small water bodies are strongly influenced and altered by climatic changes and human disturbances. These changes are the main factors structuring the invertebrate community of these systems due to their passive lifestyle. Macroinvertebrate organisms are vulnerable to climate-induced changes which are usually severe and sophisticated. It depends on the species tolerant-threshold and responses. Studies have shown that differences in species responses due to hydrobiological changes result in species composition dynamism and structure. The present ecological study will add to the information on benthic macroinvertebrates inventory of eutrophic temporal water bodies. Such water bodies are used to stimulate the interest of greenhorn ecologists and naturalists. Furthermore, it helps in better understanding of land-water interactions.

Materials and methods

Study Sites and Collection of Samples

Macroinvertebrates collected during an ecological study of pools around Delta State University Third Campus environs, Abraka, Delta State, Nigeria. From the 26th to 28th of October 2018, during the last phase of the raining season months, three shallow lentic pools investigated were randomly designated stations 1 to 3. These pools were created as canals to drain flood around the Faculties of Arts and Social Sciences and its surroundings. The pools varied in depths from 0.5-1.0m with a concreted bottom. Station 1 was the shallowest; transparent with few debris. Dead earthworms were also prominent. Station 3 was the deepest, non-transparent green water with abundant debris and very oily surface. Dead earthworms and vertebrates like tadpoles littered the water surface.

Two litres of water samples were collected in washed sterile plastic bottles from the pools for determination of limnological parameters using standard methods referenced in APHA, 1998. Furthermore, professional scooped-net was used to collect the benthic macroinvertebrates in the water surface. The bottom sampled, wood, sticks and debris collected and taken to the laboratory. In the laboratory, the wood, sticks and debris rinsed thoroughly, sorted and counted both dead and the living macroinvertebrates. Identification was made to family and some to species level by reference to standard keys including Quigley, 1977 and Oscoz *et al.*, (2011),

Statistical Analyses

Simple univariate analysis performed on the physical and chemical parameters with Past 365 (version 1.96). Differences in the limnological variables among the studied pools checked with one way analysis of variance. The species percentages proportionate abundance (PA) is presented. The Canonical correspondence analysis used for the assessment of the relationships between log (x + 1) transformed macroinvertebrates and environmental variables. Moreso, the heterogeneity of the macroinvertebrates in the pools were investigated using log (x + 1) transformed macroinvertebrate data.

At each site, biological indices such as species richness, dominance, Shannon index, Simpson index, evenness, equitability were evaluated using Past software 365 (version 1.96).

Results and discussion

The mean data of the physical and chemical properties of the studied pools presented in Table 1. These physicochemical parameters at the studied pools did not vary significantly except nitrate ($p<0.05$). In the present investigation, the air temperature varied between the maximal 31°C in station 3 and a minimal 27°C in station 2. However the water temperature was contrary, the maximum (29°C) was in station 2 while the minimum (24°C) was in Station 3. The lower water temperature in station 2 attributed to the cover received from the pedestrian pathway close to station 2. The studied pools revealed well-oxygenated despite the apparent eutrophication signs. The pools were also weakly acidic (6.18 – 6.47). The acidic nature of the pools is in agreement with the tropical rainforest geographical zones of the study area (Iloba *et al.,* 2018).

The present study identified intense physicochemical parameters in the pools attributable to closeness to the University car park as well as the influx of grease and oil through the flood (Erhunmwunse *et al.*, 2013). The unusually high concentrations metals and anions (calcium, magnesium, nitrate, phosphate and sulphate) revealed high primary production evident from the deep green water due to the impact of grease and oil influx from the university car park. The influx of grease and oil into the pools during the rains impacted eutrophication resulting in the death of some organisms (Ouyang *et al.*, 2018). The prevalent organic process in the pools instituted by the high calcium, magnesium, nitrate, chloride, phosphate, sulphate, conductivity, total dissolved solids, biochemical oxygen demand recorded in this study, is attributable to the influx of nutrient impacting-substances from the environment (Barbosa *et al.* 2001).

The high nutrient parameters particularly phosphate and nitrate, are an indication of poor water quality (Ouyang *et al.,* 2018). The potential source, as earlier discussed, is from the University car park next to the pools.

Table1. Mean (±SD) values of physical and chemical characteristics of the sampled pools.

Sample	Station 1	Section 2	Station 3	F-Anova	Probability
Air temperature	29.5±0.71	27.5±0.71	27.5±4.95	0.31	0.75
Water temperature	28±1.41	28.5±0.71	25±1.41	4.78	0.12
PH	6.5±0.41	6.56±0.13	6.35±0.24	0.59	0.61
Conductivity µS/cm	111.65±1.06	126.6±6.22	117.4±9.33	2.69	0.21
TDS mg/L	228±107.8	89.6±76.93	204±62.22	1.54	0.35
Alkalinity mg/L	22.5±3.54	30±14.14	27.5±3.54	0.39	0.71
DO mg/L	7.4±1.98	8±4.24	6.8±3.96	0.06	0.95
BOD mg/L	2.9±1.27	3.2±2.55	3±3.11	0.01	0.99
Total alkalinity mg/L	150±14.14	160±33.94	147±4.24	0.20	0.83
Calcium mg/L	88±11.31	87±24.04	85±21.21	0.01	0.99
Magnesium mg/L	62±2.83	73±9.90	62±16.97	0.61	0.60
Nitrate mg/L	19.65±0.21	20.6±0.85	21.95±0.07	10.41	0.04*
Chloride mg/L	2.4±2.12	1.95±0.07	2.5±2.12	0.06	0.95
Phosphate mg/L	1.6±1.13	1.9±1.27	2.5±0.99	0.32	0.75
Sulphate Mg/L	3.3±1.13	3.6±1.70	3.6±0.99	0.35	0.97

Probability>0.05- not significant

The high nutrient parameters noted in this study, in addition to the high BOD did not corroborate the high oxygen concentrations attributable to the shallow nature of the pools. The high calcium level detected in this study was in the range of 70- 80mg/L is higher than the acute toxicity Calcium level of 50mg/L required to kill aquatic organisms in hard waters (Pyle and Conture, 2011). The level of calcium in the studied pools is attributable to the concrete and agricultural catchment on campus (Potasznik *et al.*, 2015). This study recorded a total of seventeen (17) taxa, from sixteen (16) families with a total of 460 individuals belonging to the following genera; Odonata (28.91%) Oligochaeta (26.09%), Diptera

(24.57%) Hemiptera (12.39), Gastropoda (4.35%), Coleoptera (3.48%), and Arachnida (0.22%) (Table 2). This number is smaller than those reported for river systems in the study environment by Arimoro *et al.*, (2008) and Iloba *et al.*, (2019). This difference might be due to human impact (grease, oil and fuel combustion) and the temporal nature of the study stations. The prevalence of the class insecta in the present study could be due to the water quality, food availability, presence and abundance of predator species as well as degree of effective competition favourable to this group of macroinvertebrates' fauna in these pools. Aquatic studies globally have also noted class Insecta as always dominating water systems organically, a likely reason for the high abundance of the insect in this study (Obolewski *et al.*, 2014). The presence and number of chironomus larvae indict organically polluted water. The family Lumbricidae represented by only *Lumbricus terrestis Linnaeus* 1758 was the most abundant presented. Dead *L. terrestis* in parenthesis was the most macroinvertebrates frequently encountered. Only one living earthworm was encountered in both stations 2 and 3.

Table 2. List of Macroinvertebrates, abundance, and relative abundance(RA) in the studied pools. Bold values represent subtotal of the various taxa, dead organisms in parenthesis, RA; bold at taxa level and light at specific.

Branch	Taxa	Family	species	STN 1	STN 2	STN 3	Total	RA%
Annelida	Oligochaeta							
		Lumbricidae	*Lumbricus terrestis; Linnaeus 1758*	0(50)	1(50)	1(13)	120	26.09
Mollusca								
	Gastropoda							
		Planorbidae	*Bulinus senegalensis;* Müller, 1781	-	2	1	3	0.65
		Pleuroceridae	*Elimia sp;H Adams & A.Adams 1854*	1	1	15	17	3.70
Subtotal				1	3	16	20	4.35
Anthropoda								
	Insecta							
	Hemiptera Hemiptera							
		Notonectidae	Backswimmer(*Notonecta glauca*); *Linnaeus 1758*	8	0	0	8	1.74
		Gerridae	*Gerris sp. Fabricius; 1794*	7	0	1	8	1.74
		Corixidae	*Corixa sp.; Geoffroy 1762*	0	0	1	1	0.22
		Nepidae	*Ranatra linearis, Linnaeus 1758*	6	13	5	24	5.22
			Nepa apiculate, Uhler 1862	5	6	5	16	3.48
Subtotal				26	19	12	57	12.39
	Coleoptera							
		Gyrinidae	*Gyrinus sp. Geoffroy 1762*	2	1	4	7	1.52
		Psephenidae	*Schinostethus sp.*Waterhouse,*1880*	2	0	1	3	0.65
		Elmidae	*Elmidae sp, Curtis,1830*	1	0	2	3	0.65
		Halipidae	*Brychius hungerfordi, Spangler,1954*	0	1	2	3	0.65
Subtotal				5	2	9	16	3.48
	Diptera							
		Chironomidae	*Chirinomus larvae collect,Meigen,1803*	48	47	18	113	24.57
	Odonata							
		Gomphidae	*Ophiogomphus sp,Selys,1854*	9	2	11	22	4.78
		Aeshnidae	*Aeshna umbrosa, Walker, 1908*	13	7	40	60	13.04
		Cordulegastridae	*Spiketail*	10	27	14	51	11.09
Subtotal				32	36	65	133	24.57
	Arachnida	*Pisauridae*	*Dolomedes sp.; Latreille,1804*	0	0	1	1	0.22
	Gross Total			77	68	108	460	

The death of *L. terrestis* could mark the onset of harsh environmental conditions for them paving the way for the dominance of the family Odonata. The onset of dry season reduced the water level, concentrates nutrients, impacting dark green on the pools. The structure and abundance of Macroinvertebrates modulated by these processes lead to displacement. The imbalance in nutrient elements can either lead to the growth or death of aquatic organisms, thereby distorting the re-establishing or distorting the ecological balance (Renuka, 2014). The viability of organisms depends on their ability to attain homeostasis (which is species-dependent) within the allowable time, otherwise death (Barbosa *et al.*, 2001). The latter could be another plausible/ probable reason for the death of *Lumbricus terrestis* in pools. Thus the pop of aquatic ecosystem is self-correcting evident from the low dominance in all pools. The sites morphology, climatic factors and nutrient-enrichment due anthropogenic activities around the pools (Watershed) are environmental stresses which resulted in the death and elimination of earthworms, tadpoles. The pools ecological processes are linked to the drainage basin (concrete) as well as the lateral surroundings (University car pack) (Cocchiglia *et al.*, 2012). Fish kills have been reported in aquatic systems with high biochemical oxygen demand intense nutrient accumulation (Ouyang *et al.*, 2018). The low number of gastropods is attributable to the deleterious concrete substrate and the temporary nature of the pools (Browm *et al.*, 2010).

The class Odonata, although with three families, now the most abundant with 133 individuals. The abundance of Odonata is suggestive of the fact that they were among the first to colonize the habitat, hence multiplied successfully in the environment before other groups arrived. The high number of Odonata substantiates Braccia *et al.*, (2007), who reported that Odonata is early colonizers of new lentic habitats. Bernath *et al.*, (2002) states that organic load serves as distant visual cues to adult Odonata in detecting polarization and reflecting the light of suitable habitat to oviposit. Stagnant vernal pools with high silts and debris guide the Odonates to colonize these water bodies earlier before the arrival of other groups arrived and hence given them an advantage over others in dominating the habitat. Habitat stability must have also contributed to the dominance of Odonates is habitat stability, particularly in station 3, where their numbers were notably higher. This habitat stability conforms with Biber (2002), who stated that Odonata species are sensitive to habitat disturbance.

The abundance of Hemipteran not linked to the preponderance of food in the pools. Corixidae feeds on Periphytes, blood worms and Oligochaetes, which are almost abundant under high nutrient conditions (Lock *et al.,* 2013). The low number of Coxidae under adequate food availability in this study is due to the dry phase of the pools which is reportedly unfavourable to the survival of Coxidae juveniles (Mabidi *et al.,* 2017). This condition is actually in station 3. It explains the low number of earthworms and Chironomids in station 3, where the numbers of predator species like Odonata and Hemiptera were highest. The group's opportunistic feeding favours the number of Corulegastridae (Spiketail).

The low number of Coleoptera, particularly Gyrinus, is an indication that the water body is not pollution-free. The status of Gyrinus in this study is similar to Iloba *et al.,* (2019) and contrasted Arimoro *et al.,* (2007), who reported other less tolerant species such as the EPT species and Odonata is an indication of clean water conditions. The studied greenish-brown pools with debris, and sticks well camouflaged for the *Aeshna umbrosa* naiads, Walker, 1908, favoured its occurrences in this study.

Taxa richness (S) varied at the different pools due to the different habitat, water quality structure and degree human disturbances (Obolewski *et al.,* 2014). Taxa richness in the pools was low, which is found to agree with hyper nutrient water bodies (Ouyang *et al.*, 2018). A critical examination of the diversity indices table revealed a decline in macroinvertebrate diversity indices except for dominance. When the dead *L. terrestis* was a consideration (Not-pooled) (Table 3), revealing the association between species richness and diversity value.

The Shannon_H diversity index inference the studied pools as moderately polluted with relatively high significant macroinvertebrate variation (Table 3). However, Lenat *et al.*, (1980) reported that Margalef's water quality index with values less than three (3) indicate poor water conditions. Margalef's index value for this study was less than 3, except in station 3 in this study. Indices less than 3 are an indication of deplorable water conditions.

At the species category, the most predominant species besides the dead earthworms was the chironomus larvae (Table 2). The preponderance of Diptera in this station also gives further credence to this claim, as Diptera (Chironomus larvae) and Oligochaetes have been known to tolerate poor water conditions. The dominance of Chironomids in the pools is typical indicators of temporal water bodies (Epele *et al.*, 2016). When the macroinvertebrate data of all stations were compared using diversity t-test (Table 3).

It was evident that the stations were significantly different in the pooled data (data with the dead individuals) while with the elimination of the dead macroinvertebrates (not pooled), stations 1 and 3 diversities became non-significantly different (T= 1.74, p= 0.083). Biological indices test revealed low dominance and distribution of individuals over taxa or species is less evenness and less equitable.

Table 3. Taxa richness, diversity, evenness dominance indices and diversity test of Macroinvertebrates in Studied Pools.

	Pooled			Not-Pooled		
	STN1	ST2	STN3	STN1	ST2	STN3
Species Richness Indices						
Taxa_S(pooled)	13	11	16	12	11	16
Individuals	167	158	136	112	108	125
Margalef	2.345	1.975	3.058	2.331	2.136	3.107
Diversity Indices						
Shannon_H	1.917	1.702	2.202	1.917	1.623	2.16
Simpson_1-D	0.7898	0.7675	0.8496	0.7738	0.7253	0.8361
Dominance_D	0.2102	0.2325	0.1504	0.2262	0.2747	0.1639
Evenness_e^H/S	0.5243	0.4987	0.5654	0.5666	0.4606	0.5422
Equitability_J	0.7483	0.7098	0.7944	0.7714	0.6767	0.7792
Diversity Test						
STN 1	-	1.9719			2.0685	
T-test		0.049*			0.034*	
P value						
STN 2			-4.3723 0.0000*			-3.8915 0.0000*
STN 3	2.319 0.021*		1.74 0.083			

The CCA analysis of macroinvertebrate taxa, environmental variables are associated with studied Stations isolated two axes (Fig.1). The directions of the stations and environmental vectors revealed that different environmental factors influenced different organisms at the various stations (Pirvu *et al.*, 2015).

The environmental factors affecting the organisms are in the first axis. The inherent value in the first axis is 0.14796 accounting 63.06% variations of the ecological status of macroinvertebrates in the studied pools. The second axis had 0.090464 eigenvalues with 37.94% variance.

In station 1, air temperature, total dissolved solids, chloride influenced the Backswimmers (Notonecta glauca, Linnaeus, 1758), *Elimidae* sp, *Curtis,*1830, *Schinostethus* sp *Waterhouse,* 1880, *Gerris* sp, *Fabricus,* 1794, *Ghomphidae. Nepa apiculata Uhler,* 1862, *Chironomus larva, Ranatra linearis, Linnaeus,* 1758 and *Bulinus senegalensis Uhler* 1862, were influenced by calcium, water temperature, pH, DO, alkalinity, conductivity and BOD while nitrate and phosphate influenced *Aestnidae, Gyrinus sp* Geoffroy, 1762*,* in station 3. The CCA plot revealed the abundance of the family Pleuroceridae anchored on factors other than water quality. Alkalinity concentration impacted on a relatively high number of Cordulegastridae.

The Bray-Curtis cluster analysis revealed differences in the macroinvertebrate abundances (Fig. 2). Similarities (Low distances) detected in some species. These include between backswimmers and Gerris sp *Fabricius,* 1794, *Schinostethus* and *Elimidae,* *Brychius* hungerfordi Spangler, 1954 and *L. terrestis, Renatra* and *Nepa* sp while *Pleuroceridae* and *Aeshnidae* share maximum dissimilarities during this study, identifying the most diversified and favoured species (Figs. 1 and 2).

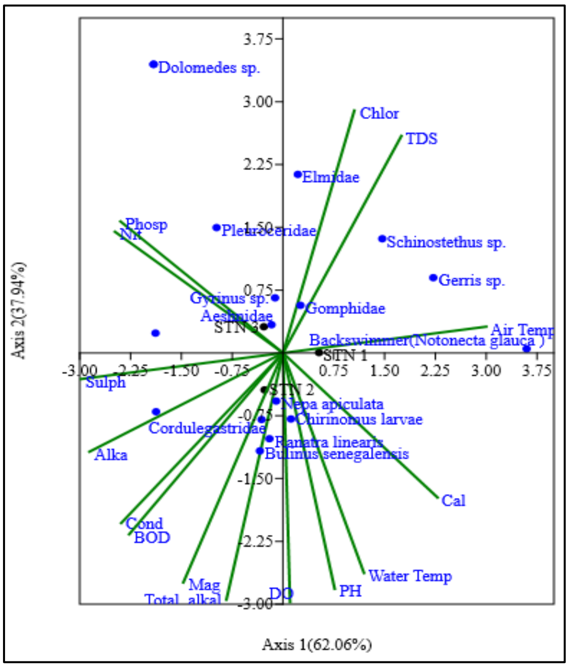

Fig. 1. Triplot of first and second CCA axes of macroinvertebrate taxa, environmental variables and associated studied Stations.

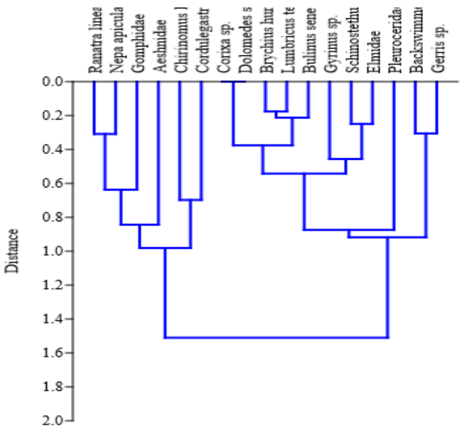

Fig. 2. Bray-Curtis cluster analysis of the macroinvertebrates abundance.

In summary, the studied pools did not support an array of macroinvertebrates. The pools are no suitable refugia and repositories of this group of organisms due to the impact of climate, eutrophication and human activities around the pools. The study revealed that the macroinvertebrates assemblages fluctuated with climatic and environmental factors. Excessive nitrate, phosphate, biochemical oxygen demand, calcium, and magnesium, human-related activities impacted on the benthic macroinvertebrates.

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