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Macroinvertebrates as Bioindicators of Water Quality Assessment in a Tropical Stream

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Abstract: The study evaluated the physicochemical properties and macroinvertebrates abundance of the Iyi-agu stream located at Ozzi-Edem Nsukka, Southeastern Nigeria. Samples were collected fortnightly at three sampling points: upstream, midstream, and downstream from June to August 2019 for physicochemical analysis and macro-invertebrate studies. The monthly variations of macroinvertebrates and physicochemical properties were analyzed using descriptive statistics and correlation matrices. Three species of macroinvertebrates: Hirudo medicinalis, Nsukkadrillus mbae, and Anopheles gambiae were recorded. Hirudo medicinalis showed a weak correlation with nitrate (r = 0.424, p = 0.028) while Anopheles gambiae correlated strongly with nitrate (r = 0.644, p = 0.0001) and depth (r = 0.687, p = 0.0001) respectively. Nitrate and depth were the major factors that influenced the abundance of macroinvertebrates. The macroinvertebrate abundance was a good biological indicator of the water quality of the Iyi-agu stream. Therefore, macroinvertebrates are a suitable option that should be considered in biological assessments of water bodies.

Keywords: Macroinvertebrates, physicochemical, Iyi-agu stream, Ozzi-Edem, Nsukka

1. INTRODUCTION:

Healthy water resources are vital for the existence of living organisms [1]. Water quality serves many functions, ranging from serving as a solvent for most chemicals to serving as a habitat for many organisms. Aquatic organisms such as insects and amphibians depend on the water at certain stages of their life and their breeding sites [2]. The water quality of aquatic ecosystems changes with the seasons, which profoundly influences the abundance of aquatic organisms [3], [4]. Anthropogenic activities and natural processes such as flooding, weathering, geochemical and geological features of the ecosystem, and the ever-increasing world population have sustained continual changes in the natural water sources [5]. As a result, there continue to be improvements in physical, chemical, and biological parameters that affect water quality. Therefore, regular monitoring of water bodies is essential to determine these changes from time to time [6]. The biological criteria include an integrated, systematic measurement of the health of water bodies health over time. Such biological indicators use biological community measures for lower trophic level organisms, such as algae or benthic macroinvertebrates, and upper trophic level animals, such as fish. The macroinvertebrate distribution and productivity rates in water bodies are largely determined by physiochemical factors [7]. In recent years, due to the growing effect of human activities and climate change on the freshwater environment, the amount of available water supply is slowly decreasing worldwide, and the need for frequent water quality assessment has become increasingly significant. Therefore, the study evaluated physicochemical properties and macro-invertebrates present in the Iyi-agu stream.

2. MATERIALS AND METHODS

Study area

Iyi-agu stream is located at Ozzi-Edem community in Nsukka Local Government Area, Enugu State, Southeastern Nigeria (figure 1). The stream remains a great freshwater resource to the community for domestic and agricultural purposes such as drinking, washing, bathing, and irrigation of crops cultivated in nearby farms. The community is known for the production of pepper, tomato, maize, and garden egg. The sampled points are located at latitude 6°50´17.72´´N, longitude 7°20´23.46´´E (upstream); latitude 6°50´20.75´´N, longitude 7°20´26.07´´ E (midstream) and latitude 6°50´19.15´´N, longitude 7°20´26.05´´E (downstream). Iyi-agu stream lies within the tropical wet and dry climate region, characterized by strong seasonality in the distribution of rainfall and temperature.

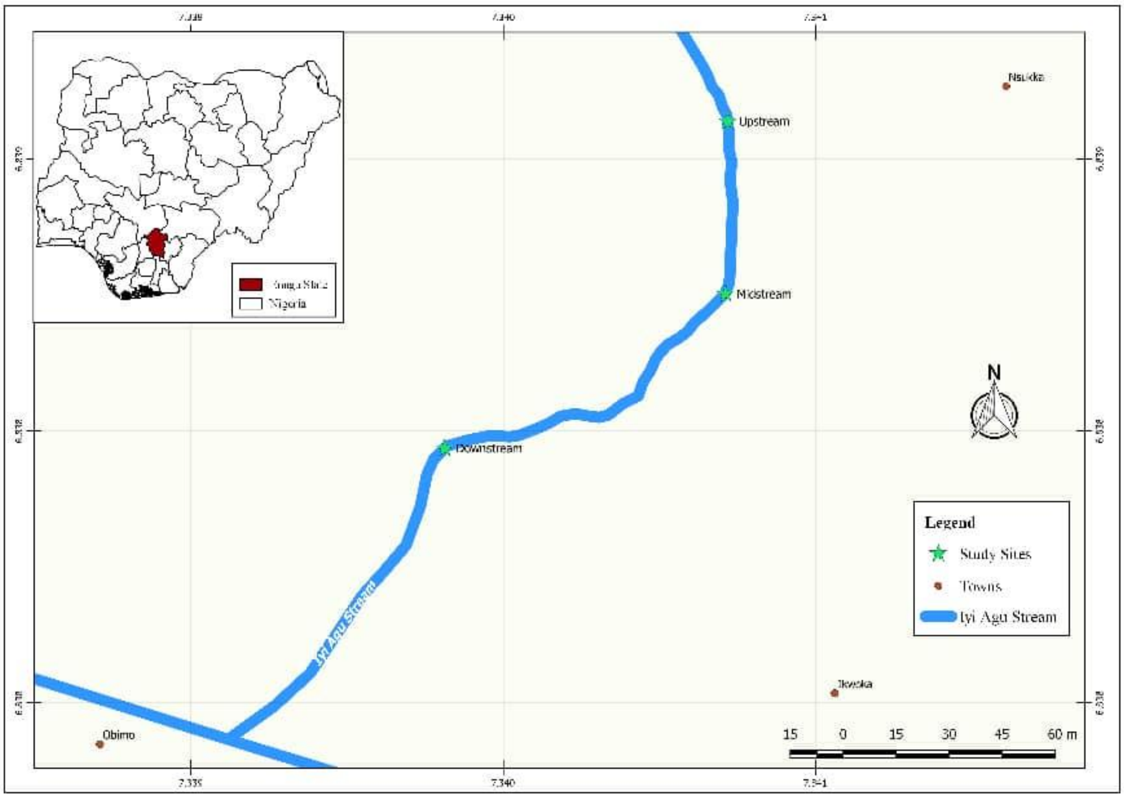

Fig.1: Study sites at Iyi-agu stream, Ozzi-Edem, Nigeria

Study design

This study lasted for three (3) months, from June to August 2019. Three sampling points were chosen within the stream: upstream, midstream, and downstream. The sampling points were selected after a reconnaissance survey of the stream. These sampling points were selected in such a way that they were representatives of the water body [1].

Analysis of water samples

Water samples were collected from three sampling points between the hours of 6:00 am to 8:00 am fortnightly for a period of three months. The sample bottles were rinsed thoroughly with the stream water and then dipped below the water surface. The water samples were fixed on-site by the addition of 1.0ml manganese sulphate solution ($MnSO_4$) and 1.0ml of alkaline potassium iodide to prevent changes in its intrinsic quality. The physicochemical properties investigated include the following: chemical oxygen demand, dissolved oxygen, temperature, biological oxygen demand, turbidity, alkalinity, depth, nitrate, electrical conductivity, pH, total suspended solids, and total dissolved solids. Some parameters such as the temperature, water depth, and pH were determined in situ using a mercury-in-glass thermometer (0 °C–100 °C), 20 cm graduated meter rule, and HANNA pH meter (model H198129) respectively, while other physicochemical parameters were analyzed in the laboratory following the analytical methods recommended by APHA [8].

Macroinvertebrate studies

Macro-invertebrates were sampled fortnightly for three months, from June to August 2019. A standard scooping net of 0.3mm mesh size was used for the collection of macro-invertebrates. The collections were made at three sampling points using the kick sampling method. Sorting collected macro-invertebrates was done immediately on site. The sorted samples were then preserved in small vials containing 70% formalin and transported to Entomology Laboratory, Department of Zoology and Environmental Biology, the University of Nigeria Nsukka for identification using relevant keys [9].

Data analysis

Quantitative descriptive analysis of the physicochemical properties and macroinvertebrate abundance was performed using Statistical Packages for Social Sciences (SPSS) version 25.0 (IBM Corporation, Armonk, USA). The results obtained were subjected to analysis of variance (ANOVA) to test significance at a level of 0.05 between the three sampling points. Correlation analysis was used to determine the composition and distribution of macro-invertebrates in relation to the physicochemical properties of the stream.

3. RESULTS

Physicochemical properties of Iyi-agu Stream

The total dissolved solids (TDS) had the highest maximum value (165.81 ± 0.27), while turbidity had the lowest minimum value (table 1). The chemical oxygen demand (COD) was recorded higher in August (4.75± 0.03mg/l) than the values recorded in June and July. The concentration of dissolved oxygen and total dissolved solids were significantly higher during July than in June and August, respectively. The electrical conductivity and alkalinity for August were higher than the values observed in June and July. In June, temperature and total suspended solids values did not differ significantly between the stations ($p > 0.05$).

Table 1: Monthly and Station variations in the physicochemical properties of Iyi-agu stream, Ozzi-Edem, Nsukka from June to August, 2019

Months	Physicochemical properties												
	Stations	COD (mg/l)	BOD (mg/l)	DO (mg/l)	EC (µs/cm)	pH	TSS (mg/l)	TDS (mg/l)	Nitrate (Mg/l)	Alkalinity (mg/l)	Temp. (°C)	Turb. (NTU)	Depth (m)
June	Up stream	4.25 ± 0.03^{b1}	5.25 ± 0.03^{a1}	5.90 ± 0.17^{a2}	20.83 ± 0.23^{b2}	8.45 ± 0.03^{b3}	78.93 ± 0.27^{a1}	134.15 ± 0.23^{b2}	0.37 ± 0.01^{b2}	7.71 ± 0.33^{a1}	21.50 ± 0.29^{a1}	2.00 ± 0.00	21.00 ± 0.58^{c1}
	Mid-stream	4.45 ± 0.03^{c2}	5.65 ± 0.03^{c2}	6.00 ± 0.11^{a2}	18.98 ± 0.27^{a1}	8.15 ± 0.09^{a3}	80.00 ± 5.01^{a1}	128.95 ± 0.32^{a2}	0.26 ± 0.00^{a3}	8.69 ± 0.25^{b1}	21.50 ± 0.29^{a1}	2.00 ± 0.00^{1}	7.50 ± 0.29^{b1}
	Down stream	4.15 ± 0.03^{a1}	5.35 ± 0.03^{b1}	5.75 ± 0.20^{a2}	21.16 ± 0.28^{b1}	8.45 ± 0.03^{b2}	83.05 ± 0.31^{a1}	142.80 ± 0.23^{c2}	0.24 ± 0.03^{a1}	7.91 ± 0.00^{ab1}	22.50 ± 0.29^{a1}	2.00 ± 0.00	5.50 ± 0.29^{a3}
July	Up stream	4.65 ± 0.09^{b2}	5.30 ± 0.06^{b1}	6.80 ± 0.06^{b3}	18.11 ± 0.32^{a1}	7.35 ± 0.09^{a1}	88.35 ± 0.53^{a2}	165.81 ± 0.27^{c3}	0.26 ± 0.00^{a1}	8.81 ± 0.44^{a2}	23.50 ± 0.29^{b3}	2.00 ± 0.00^{a}	20.50 ± 0.29^{c1}
	Mid-stream	4.30 ± 0.06^{a1}	5.10 ± 0.06^{a1}	6.50 ± 1.11^{a3}	19.98 ± 0.25^{b1}	7.65 ± 0.09^{a2}	115.89 ± 0.29^{b3}	153.24 ± 0.19^{b3}	0.19 ± 0.00^{a1}	8.84 ± 0.03^{a1}	22.50 ± 0.29^{a1}	1.50 ± 0.29^{a1}	9.50 ± 0.29^{b2}
	Down stream	4.55 ± 0.03^{b2}	5.70 ± 0.06^{c3}	6.50 ± 0.00^{a3}	20.45 ± 0.06^{b1}	7.60 ± 0.12^{a1}	120.96 ± 0.29^{c2}	147.46 ± 0.30^{a3}	0.24 ± 0.00^{b1}	9.11 ± 0.05^{b2}	22.00 ± 0.00^{a1}	2.00 ± 0.00^{a}	5.00 ± 0.00^{a2}
August	Up stream	4.75 ± 0.03^{c3}	5.70 ± 0.06^{b2}	5.35 ± 0.03^{c1}	24.78 ± 0.33^{b3}	7.50 ± 0.17^{a2}	86.26 ± 0.31^{b2}	125.15 ± 0.32^{c1}	0.24 ± 0.00^{b1}	10.77 ± 0.26^{a3}	22.00 ± 0.00^{a2}	2.00 ± 0.00	20.50 ± 0.29^{c1}
	Mid-stream	4.25 ± 0.03^{a1}	5.65 ± 0.03^{b2}	4.15 ± 0.09^{a1}	22.22 ± 0.27^{a2}	7.35 ± 0.03^{a1}	88.42 ± 0.31^{c2}	110.13 ± 0.30^{a1}	0.22 ± 0.00^{a2}	12.03 ± 0.29^{b2}	22.50 ± 0.29^{a1}	2.00 ± 0.00^{1}	10.00 ± 0.00^{b3}
	Down stream	4.55 ± 0.03^{b2}	5.45 ± 0.03^{a2}	4.70 ± 0.06^{b1}	24.37 ± 0.28^{b2}	7.55 ± 0.03^{a1}	83.74 ± 0.30^{a1}	123.00 ± 0.35^{b1}	0.24 ± 0.00^{b1}	11.02 ± 0.26^{a3}	22.50 ± 0.29^{a1}	2.00 ± 0.00	4.50 ± 0.29^{a1}

Macroinvertebrates of Iyi-agu stream

Three species of macroinvertebrates were found at the stream; Hirudo medicinalis, Nsukkadrillus mbae and Anopheles gambiae. The abundance of macro-invertebrates was higher in June than July and August (table 2). However, macroinvertebrates were more abundant during June (38%) than July (27%) and August (30%). Nsukkadrillus mbae has the highest mean occurrence, followed by Hirudo medicinalis and Anopheles gambiae having the least (figure 2).

Table 2: Monthly and station variations in the composition and relative abundance of macro-invertebrates

Month	Stations	Species	Number collected	Relative abundance
June	Up Stream	Hirudo medicinalis	10	0.11
		Nsukkadrillus mbae	0	0
		Anopheles gambiae	3	0.03
	Subtotal		**13**	**0.14**
	Mid-stream	Hirudo medicinalis	5	0.05
		Nsukkadrillus mbae	6	0.06
		Anopheles gambiae	0	0
	Subtotal		**11**	**0.11**
	Down stream	Hirudo medicinalis	0	0
		Nsukkadrillus	12	0.13

		mbae		
		Anopheles gambiae	0	0
	Subtotal		**12**	**0.13**
July	Up Stream	Hirudo medicinalis	8	0.08
		Nsukkadrillus mbae	2	0.02
		Anopheles gambiae	0	0
	Subtotal		**10**	**0.1**
	Mid-stream	Hirudo medicinalis	3	0.03
		Nsukkadrillus mbae	4	0.04
		Anopheles gambiae	0	0
	Subtotal		**7**	**0.07**
	Down stream	Hirudo medicinalis	0	0
		Nsukkadrillus mbae	10	0.1
		Anopheles gambiae	0	0
	Subtotal		**10**	**0.1**
August	Up Stream	Hirudo medicinalis	12	0.13
		Nsukkadrillus mbae	0	0
		Anopheles gambiae	2	0.02
	Subtotal		**14**	**0.15**
	Mid-stream	Hirudo medicinalis	3	0.03
		Nsukkadrillus mbae	4	0.04
		Anopheles gambiae	0	0
	Subtotal		**7**	**0.07**
	Down stream	Hirudo medicinalis	0	0
		Nsukkadrillus mbae	8	0.08
		Anopheles gambiae	0	0
	Subtotal		**8**	**0.08**

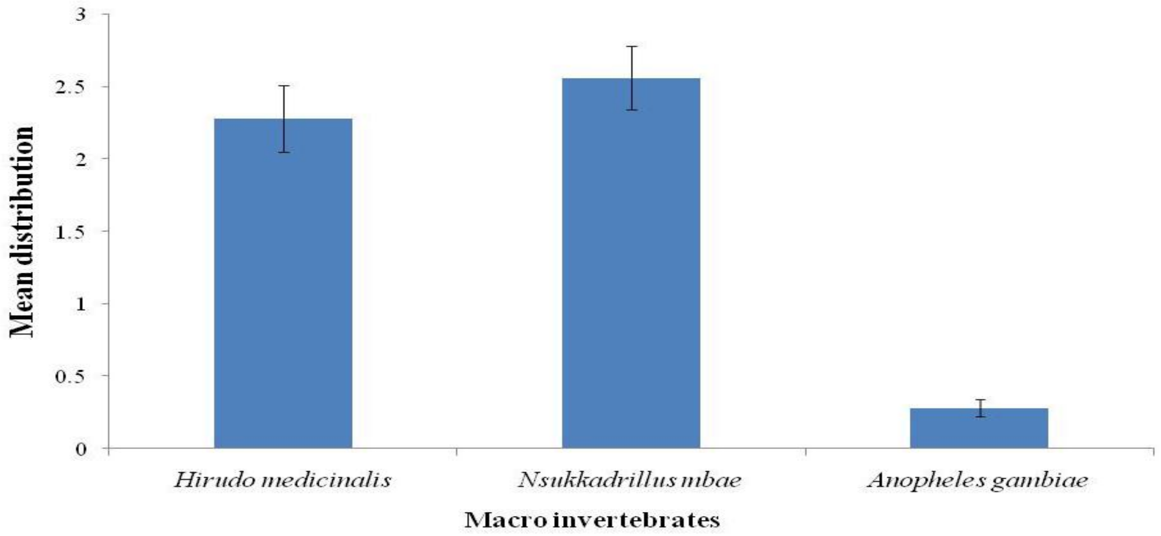

Fig 2: Mean occurrence of macroinvertebrates in Iyi-agu stream

Relationship between the physicochemical properties and macroinvertebrates of Iyi-agu stream

The relationship between physico-chemical properties and macro-invertebrates in Iyi-agu stream were presented in table 3. Hirudo medicinalis showed a weak positive correlation with nitrate (r = 0.424, p = 0.028) and strong positive correlation with depth (r = 0.880, p = 0.0001). There was strong negative correlation between Nsukkadrillus mbae and depth (r = -0.824, p = 0.0001). Anopheles gambiae also correlated strongly and positively with nitrate (r = 0.644, p = 0.0001) and depth (r = 0.687, p = 0.0001) respectively. There was also an evidence of correlation between macro-invertebrates. Nsukkadrillus mbae showed strong negative correlation with Hirudo medicinalis (r = -0.760, p = 0.0001), while Anopheles gambiae recorded a strong positive and negative correlation with Hirudo medicinalis (r = 0.681, p = 0.0001) and Nsukkadrillus mbae (r = -0.591, p = 0.001) respectively.

Table 3: Correlation matrix showing the relationship between the physicochemical properties and some macro invertebrates in Iyi-agu Stream, Ozzi Edem, Nsukka

	COD	BOD	DO	EC	pH	TSS	TDS	Nitrate	Alkalinity	Temp.	Turb.	Depth	*Hm*	*Nm*	*Ag*
COD	1														
BOD	0.362	1													
DO	0.176	-0.380	1												
EC	0.200	0.317	-0.716**	1											
pH	-0.578**	-0.239	0.168	-0.175	1										
TSS	0.069	-0.050	0.424*	-0.204	-0.354	1									
TDS	0.117	-0.543**	0.896*	-0.675**	0.008	0.435*	1								
Nitrate	-0.094	-0.117	0.166	-0.115	0.518**	-0.452*	-0.008	1							
Alk.	0.261	0.490**	-0.748**	0.642**	-0.681**	-0.031	-0.652**	-0.415	1						
Temp.	0.080	-0.218	0.042	-0.135	-0.451*	0.108	0.401*	-0.292	0.149	1					
Turb.	0.262	0.358	-0.200	0.116	0.020	-0.441*	-0.268	0.310	0.116	-0.217	1				
Depth	0.286	-0.175	0.190	-0.054	-0.070	-0.313	0.167	0.490**	-0.104	0.053	0.069	1			
Hm	0.302	0.069	0.119	-0.017	-0.020	-0.346	0.001	0.424*	-0.094	-0.101	0.051	0.880**	1		
Nm	-0.221	0.188	-0.008	-0.051	0.211	0.226	0.058	-0.283	-0.130	0.144	0.068	-0.824**	-0.760**	1	
Ag	0.058	-0.087	-0.059	0.294	0.323	-0.339	-0.190	0.644**	-0.202	-0.377	0.135	0.687**	0.681**	-0.591**	1

** Correlation is highly significant at $p < 0.01$ (2-tailed). * Correlation is significant at $p < 0.05$ (2-tailed).

(COD – Chemical oxygen demand, BOD – Biological oxygen demand, DO – Dissolved oxygen, EC – Electrical conductivity, pH – Hydrogen-ion concentration, TSS – Total suspended solids, TDS – Total dissolved solids, Alk. – Alkalinity, Temp. – Temperature, Turb. – Turbidity, Hm - Hirudo medicinalis, Nm - Nsukkadrillus mbae, and Ag - Anopheles gambiae).

4. DISCUSSION

Macroinvertebrates are responsive to a variety of physicochemical properties that influence water quality. Changes in physicochemical parameters recorded during the study period were due to the climate patterns of the Iyi-agu stream. The relatively high chemical oxygen demand level recorded could have occurred due to the high rate of organic decomposition resulting from human activities, which has undesirable consequences on aquatic life [10]. These values recorded are higher than 0.10-15.0mg/l reported by Eze and Chigbu [11] in the study of the physical, chemical, and microbiological parameters of the Iyi Okai stream. The pH of the Iyi-agu stream falls within the recommended values suitable for the survival of aquatic organisms. This agrees with what was reported by other researchers in similar studies [12], [13]. The temperature values reported were within the range recommended by World Health Organization [14]. The temperature difference might be due to rainy season weather conditions [15]. The relatively high value of dissolved oxygen recorded might be attributed to the active photosynthetic process in the stream [16]. The observed range of DO is below (15.78- 17.26mg/l) as reported by Jidauna et al. [15] in their study of the effects of water quality on condition factor and fecundity of Oreochromis niloticus. Alkalinity is important for aquatic life because it protects or buffers against rapid pH changes. The value of alkalinity may be due to high temperature and increased level of bicarbonate because of a high rate of photosynthesis [17]. The electrical conductivity recorded was slightly high. High conductivity increases the corrosive nature of water [18]. Atobatele and Ugwumba [19] suggested change in conductivity values during the rainy season might be due to dilution by rainfall. The total suspended solids did not differ significantly between the stations ($p>0.05$). High TDS might be due to the presence of large number of organic salts as carbonate, bicarbonate sodium, potassium, calcium and also some non- volatile substance which become solid at room temperature [20]. TSS and TDS are indicative of materials carried in suspension and solid respectively [21]. The biodegradation of organic materials exerts oxygen tension in the water and increases the biological oxygen demand [22]. The BOD result is greater than 3.3887mg/l – 5.3725mg/l reported by Ude [23] who studied the analysis of influential physicochemical variables of Ebonyi River. Hirudo medicinalis, Nsukkadrillus mbae and Anopheles gambiae belonging to three different families (Hirudinidae, Eudrilidae, Culicidae respectively) were the species of macro-invertebrates recorded during the period of study. According to Dieter et al. [24], these macroinvertebrate taxa are sensitive to environmental chemistry of aquatic ecosystems. The composition of macro-invertebrates is influenced by ecological changes arising from the alterations of some important factors such as water quality and food availability [25]. The depth of the water was significantly recorded highest in the studied months, which influenced the composition of macroinvertebrates. This is in line with the findings of Baumgärtner et al. [26], where macroinvertebrate community patterns differed significantly between the depth zones, partly because of species turnover but primarily due to different dominance structures and climate patterns.

5. CONCLUSIONS

The study revealed the potential of the species Hirudo medicinalis, Nsukkadrillus mbae, and Anopheles gambiae as water quality indicators. The results showed that the occurrence of H. medicinalis. and N. mbae is dependent on BOD, while A. gambiae correlated negatively. Water quality assessment has become a unique feature of animal and environmental studies, which is paramount for a sustainable ecosystem. However, a detailed evaluation of the macroinvertebrate community is encouraged, particularly for a more extended period.

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