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Research Article

The Use of Benthic Macroinvertebrates and Insects for Evaluation of Kandola Shella (UDUS Stream) Status

***Samrawi, S.A.[1], Magami, I. M.[1] and Yelwa, S. M.[2]**

[1]Department of Biology, Faculty of Chemical and Life Sciences, UDUS, Nigeria
[2]Depatment of Zoology, Faculty of Chemical and Life Sciences, UDUS, Nigeria
****Corresponding Authors' email*: salmasamrawi9@gmail.com**

ABSTRACT
Kandola Shella Stream (UDUS stream) supports significant fishing and irrigation activities for the local community's daily routine needs. This study evaluated water quality using macroinvertebrates and aquatic insects from September 2023 to March 2024. Macroinvertebrates and Insect species were sampled, preserved and identified at the Entomology Laboratory of Usmanu Danfodiyo University, Sokoto using standard keys and manuals. Three biotic indices (%EPT, BMWP and ASPT) and one diversity index (Shannon-Weiner index) were used for water quality assessment. Statistical analysis showed significant differences in physicochemical parameters across the months ($p<0.05$) but not among sampling locations ($p>0.05$). A correlation was observed between physicochemical parameters and Macroinvertebrate abundance. The %EPT index indicated no sensitive species at any sampling location. Macroinvertebrate abundance was highest at location D (200 individuals), followed by location C (55), location B (50) and location A (22). The Insects' result revealed highest at location A (219), followed by location B (122), location D (103) and location C (90 individuals). The study concluded that Kandola Shella stream is slightly polluted, with minimal chemical and organic pollutants concentration. The presence of pollution-tolerant species and the absence of sensitive species, therefore, suggest the need for continuous monitoring to manage and mitigate pollution, ensuring the health of this essential water resource.

Keywords: Biotic indices; Kandola Shella; Macroinvertebrates; Pollution; Water quality

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INTRODUCTION

Water is the most important natural resource needed for the survival of all living organisms which forms the major constituent of the ecosystem. It can be sourced from rain and surface or ground water (Balan *et al.,* 2021). It is vital for all known forms of life, despite providing neither food, energy, nor organic micronutrients. The freshwater ecosystem has been identified as one of the major sources of livelihood for humans, especially in developing countries. As a result, information on the ecological status of water bodies in these areas is of great concern to the general public. Freshwater habitats provide long-term potable water for domestic consumption, recreation and also serve as sources of raw materials for some industries (Damn *et al*., 2010). Water pollution is a universal anxiety, as it affects water quality and confines water use for various purposes (Jerves-Cobo *et al*., 2018; Kebede *et al*., 2020). Anthropogenic activities and agricultural runoff that run directly into the catchment region and pass into the water bodies are the primary sources of water pollution (Etemi *et al*., 2020).

Stream water quality assessment is crucial for the preservation and management of aquatic ecosystems. Monitoring and evaluating the health of streams provide valuable insights into the impacts of human activities, pollution, and natural processes on water resources (Hawkins *et al*., 2010). Traditional approaches to water quality assessment rely heavily on physicochemical parameters such as dissolved oxygen, pH, and nutrient levels (APHA, 2017). However, these parameters may not fully capture the overall ecological condition of streams. Benthic macroinvertebrates and insects, as bioindicators, offer a complementary and integrative approach for evaluating stream water quality (Prat *et al*., 2018). Among the communities that are considered as bio indicators of water body status, benthic macroinvertebrates are the most commonly used, because they have several characteristics that make them easy to study and show clear responses when faced with adverse environmental conditions. The structure of the benthic communities in an aquatic ecosystem reflects its ecological conditions, including habitat heterogeneity and water quality (Hepp *et al*., 2010).

Aquatic macroinvertebrates constitute an important component of an aquatic ecosystem and they exhibit differential tolerances to changes in environmental conditions. They include insects, annelids (leeches), oligochaetes (worms), crustaceans (crayfish and shrimp), molluscs (clams and mussels), and gastropods (snails) (Adu, *et al.,* 2016). Benthic macroinvertebrates include insect larvae such as stonefly and mayfly nymphs, aquatic worms and crustaceans such as crayfish and gastropods such as snails. According to Arslan *et al*. (2016), benthic macroinvertebrates are important indicators of stream health and some species have bio-indicative potential: their absence or presence can therefore provide information on the state of pollution. Given the foregoing, this study aimed to assess the effectiveness of benthic macroinvertebrates and aquatic insects as bioindicators for evaluating the ecological status of the Kandola Shella stream (UDUS Stream).

MATERIALS AND METHODS

Study Area

Kandola Shella Stream (UDUS stream) is located within Usmanu Danfodiyo University Main Campus situated between Latitude 13º6’0” N and 13º8’0” N and Longitude 5º12’0” E and 5º16’0” E in Wamakko Local Government Area of Sokoto State. Sokoto State is located in the Sudan Savannah zone in the extreme North-Western part of Nigeria (Mamman *et al*., 2013). Usmanu Danfodiyo University Sokoto stream (UDUS stream) is popularly known as Kandola Shalla, it flows down to River Rima. The soil's substrate is fine sand, with a thin layer of humus and clay on top. It is encircled by vegetation, and the stream is heavily frequented by human activity such as farming, bathing, laundry, and animal grazing.

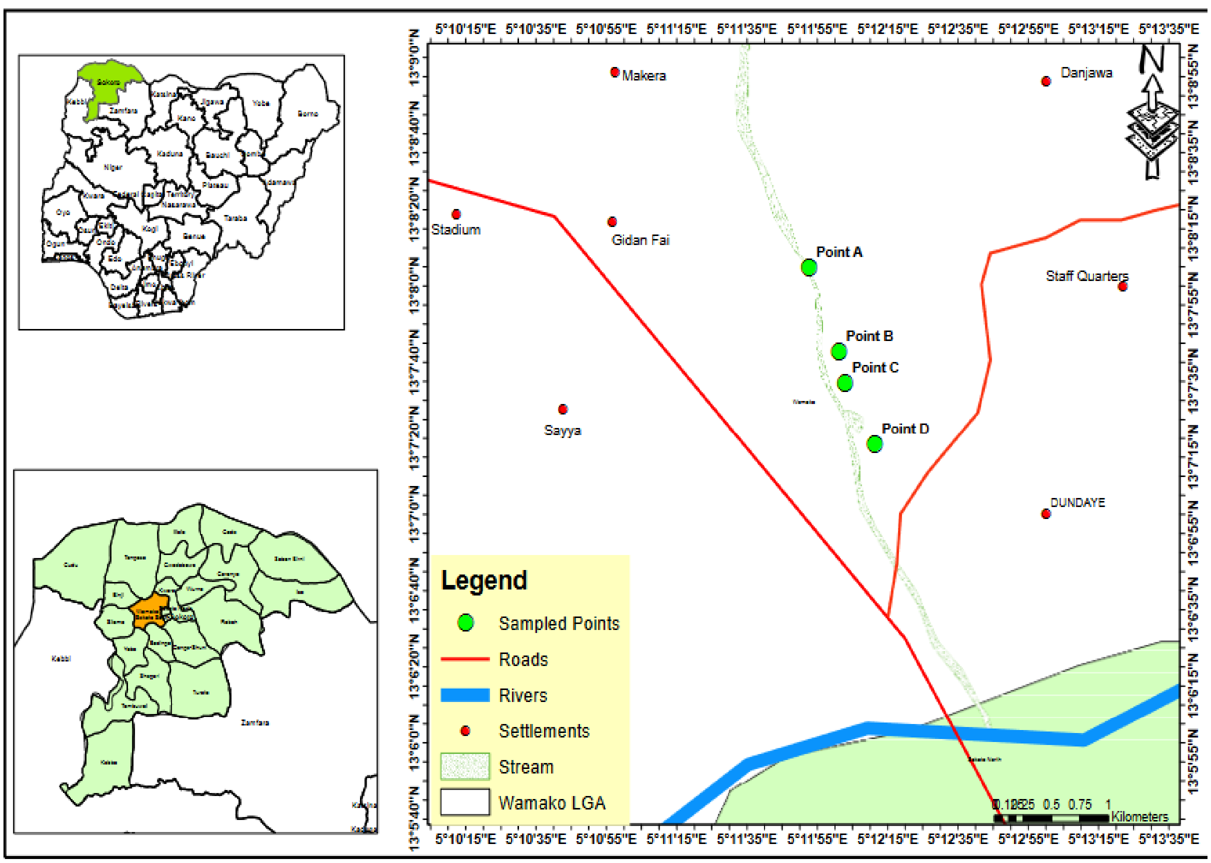

Figure 1: Map of UDUS Stream showing sampling locations (Source: Geographical Information System, UDUS 2023)

Sampling Locations
Four (4) sampling locations A, B, C and D were studied from the stream based on the differences in their anthropogenic activities.

Sampling location A: It is located on Lat. N13º8'4 and Long. E5º11'52. This is regarded as the inlet of the stream. The anthropogenic activities occurring there involves farming, washing and animals goes there to drink water and is about 1.5km from the source.

Sampling location B: It is located on Lat. N13º7'42 and Long. E5º12'1. The anthropogenic activities taking place there are farming and irrigation. It is about 1km from location A.

Sampling location C: It is located on Lat. N13º7'34 and Long. E5º12'2. This is also a mid-portion of the stream. No or less anthropogenic activities are taking place there and is about 500m from location B.

Sampling location D: It is located on Lat. N13º7'18 and Long. E5º12'11. This is regarded as the outlet of the stream. A lot of anthropogenic activities are also taking place there and these include farming, fishing, irrigation activities etc. and is about 800m from location C.

Benthic Macroinvertebrates Collection
Benthic Macroinvertebrate samples were collected from each of the four (4) sampling locations (A, B, C and D). Kick sampling method (Višinskienė and Bernotienė, 2012) that ensures the dislodgement of attached organisms from the substrate into the scoop-net was used.

Sampling was carried out with a kick net by holding the net frame firmly against the stream bottom and disturbing the substrate upstream (approximately a full arm's length) from the net with the collectors' feet and a D-frame kick sampling aquatic net for sampling non-riffle areas. This was followed by digging deeply into the substrate with the heel or toe to dislodge macroinvertebrates from the streambed. Care was taken to ensure that the plume of silt that resulted from disturbing the substrate was flowing into the net, as this plume also contained the dislodged macroinvertebrates. The samples were collected per sampling locations from all aquatic habitats (i.e., riffles, pools and vegetated margins). The collected samples were transferred into a clean plastic container and preserved in 10 % formaldehyde solution and transported to the Usmanu Danfodiyo University Sokoto Laboratory for sorting, identification and counting using compound microscope.

Sorting and Identification of Macroinvertebrates
Based on their morphological features, the collected samples were sorted and identified to the lowest possible taxon (Species, Order and Family) with the aid of a compound microscope and appropriate identification guides of De Moor *et al.* (2003), Umar *et al.* (2013), Arimoro and James (2008) they were counted and recorded.

Data Analysis
The data obtained was analysed and presented as macroinvertebrates abundance in percent. Percentage of Ephemeroptera, Placoptera and Trichoptera (%EPT), Biological Monitoring Working Party (BMWP) Index and Average Score per Taxon (ASPT) were used to assess the quality of the stream while Shannon Weiner index (H) and Evenness Index (E) were used to assess the macroinvertebrates diversity in the water body.

RESULTS
The overall benthic macroinvertebrates composition, abundance and distribution in the study locations are summarized in Table 1 and Table 2 based on family collected at each sampling location. The percentage distribution from each location indicates that location A has a total number of 22 individual organisms at 6.7%, location B has 50 at 15.3% and location C has 55 at 16.8%, while sample location D has a total of 200 individuals with 61.2%. A total number of 4 taxa out of the total of Three Hundred and Twenty-Seven (327) species of Macroinvertebrates belonging to 3 Phyla (Arthropod, Molluscs and Annelida) were collected, preserved and identified during the sampling period. However, Pouch Snails (Pulmonata) were the most encountered species with 228 individuals followed by Aquatic Worms (Lumbriculida) with a total of 37 species. This is followed by Aquatic Spiders with a total of 37 individual organisms and the least occurred macroinvertebrates were the Orb Snail with 25 species as shown in Table 1. Table 2 shows the abundance of aquatic Insects based on family collected at each sampling location. The percentage distribution from each location indicates that location A has a total number of 219 individual organisms at 41.0%, location B has 122 at 22.8%, and location C has 90 at 16.9% while sample location D has a total of 103 individuals with 19.3%. A total number of 18 taxa out of the total of Five Hundred and Thirty-Four (534) species of Aquatic Insects belonging to Phylum Arthropods were collected, preserved and identified during the sampling period. However, Damselflies (Odonata) were the most encountered species with 275 individuals followed by Dragonflies (*Aeshna* sp) with a total number of 149 individuals. This is followed by Water Striders with 36 species. The indices of water quality (%EPT), (BMWP), (ASPT) and general diversity (H), evenness (E) calculated for the four locations are presented in Table 3. Although water quality indices revealed good to excellent water quality at all the sampling locations except %EPT it show poor water quality for all the locations while diversity and evenness indices were both higher at location C.

Table 1: Order, Family and Percentage Occurrence of Benthic Macroinvertebrates Recorded at sampling locations of Kandola Shella Stream (UDUS Stream)

ORDER	FAMILY	A	B	C	D	TOTAL	OCCURRENCE (%)
Pulmonata	Physidae	-	25	32	171	228	69.7
	Planorbidae	8	5	12	-	25	7.6
Lumbriculidae	Lumbriculidae	14	-	-	23	37	11.3
Areae	Dictynidae	-	20	11	6	37	11.3
Total		**22**	**50**	**55**	**200**	**327**	**100**
Percentage (%)		**6.7**	**15.3**	**16.8**	**61.2**		

Footnote: **A**: Sampling location A, **B**: Sampling location B, **C**: Sampling location C and **D**: Sampling location D

Table 2: Order, Family and Percentage Occurrence of Aquatic Insects Recorded at Sampling Points of Kandola Shella Stream (UDUS Stream)

ORDER	FAMILY	A	B	C	D	TOTAL	OCCURRENCE (%)
Odonata	Coenagrionidae (Larvae/Adult)	117	70	36	52	277	51.8
	Aeshnidae (Larvae/adult)	63	30	13	43	149	27.9
Hemiptera	Nepidae	7	2	-	6	15	2.8
	Gerridae	-	-	36	-	36	6.7
	Belastomatidae	-	-	1	-	1	0.2
	Pleidae	-	-	-	1	1	0.2
	Geastocoridae	3	-	-	-	3	0.6
Diptera	Tabanidae (Larvae)	3	3	1	-	7	1.3
	Tipulidae (Larvae/Adult)	-	2	-	-	2	0.3
	Chironomidae (Larvae)	-	2	-	-	2	0.3
Coleoptera	Dytiscidae	17	10	3	-	30	5.6
	Staphilinidae	-	-	-	1	1	0.2
	Hydraenidae	4	-	-	-	4	0.7
	Hydrochidae	5	3	-	-	8	1.4
TOTAL		**219**	**122**	**90**	**103**	**534**	**100**
Percentage (%)		**41.0**	**22.8**	**16.9**	**19.3**		

Footnote: **A**: Sampling location A, **B**: Sampling location B, **C**: Sampling location C and **D**: Sampling location D

Table 3: Status of Water Quality of Kandola Shella Stream (UDUS Stream) based on Biotic Indices

Sampling Point	Biotic Indices Result	Biotic Indices Result	Biotic Indices Result	Biotic Indices Result	Biotic Indices Result
	%EPT	**BMWP**	**ASPT**	**SHANON WEINER**	**EVENNESS**
A	0	78	7.1	0.9	0.5
B	0	67	6.1	1.3	0.7
C	0	57	6.3	1.4	0.8
D	0	50	6.3	1.1	0.6

Footnote: %EPT- Percentage Ephemeroptera, Placoptera and Tricoptera, BMWP- Biological Monitoring Working Party, ASPT- Average Score Per Taxon

DISCUSSION

Macroinvertebrates and aquatic Insects analysis results revealed that the composition and abundance of identified species from the four (4) sampling locations were higher and more diverse at locations D and A followed by location B and the least occurrence was observed at location C. Furthermore, Order Odonata (Ashnidae and Coenagarioidae), Order Pulmonata (Planorbidae and Physidae), Order Hemiptera (Nepidae, Gerridae Gelastocoridae, Belastomatidae and Pleidae), Order Coleoptera (Dytiscidae, Staphylinadae, Hydraenidae and Hydrochidae), Order Diptera (Tabanidae, Tipulidae and Chironomidae) are the most abundant and diverse species widely distributed at all the sampling locations.

However, Odonata and Pulmonata were found to be dominant throughout the sampling period. The dominance of Odonata (aquatic insects) is similar to the observation of Imoobe (2008) in Ologe Lagoon Nigeria and that of Arimoro *et al*. (2015). The dominance of these aquatic insects may be attributed to their morphological and physiological adaptations to the various habitats, availability of food and sustained reproduction. The presence of pollution tolerant macroinvertebrates such as Odonata, Lumbriculida and Dipterans could be attributed to the effect of domestic waste and agricultural activities around the stream. Indabawa (2010) reported that Damselflies, Dragonflies and Midges are commonly found in Freshwater that considerably have organic debris. The abundance of pollution tolerance macroinvertebrates is a common feature of organically aquatic ecosystems (Atobatele *et al.* 2005; Arimoro and Osakwe 2006). In addition, the dominance of Pulmonata (Pouch Snail) is also in agreement with the dominance of Mollusks reported in Lagos Lagoon and Porto Novo Creek (Ajao and Fagade 2002). The dominant species of Orb and Pouch Snails in Kandola Shella Stream all belong to the order Pulmonata. The presence of the Coleoptera order also members of pollution tolerant and being the third most abundant taxa can be attributed to their oxygen renewal ability. Emere and Nasiru 2009 reported that most aquatic beetles (Coleopterans) can renew their oxygen supply directly from the atmosphere, they are thus unaffected by oxygen-depleting waste while others possess special adaptations for obtaining oxygen. The presence of order Hemiptera is in agreement with the finding of Bashti and Ostovan 2014 who recorded the dominance of Hemipterans in streams. The moderate abundance of Hemiptera order also coincides with the work of Hoang *et al.* 2010 who found Hemiptera to be the most abundant taxa in the Du River Basin in Northern Vietnam. Ephemeroptera, Plecoptera and Trichoptera species were found to be absent throughout the sampling period. The absence of these species might be due to their sensitivity to a polluted environment and the deteriorated state of the stream as a result of different anthropogenic activities (Arimoro and Ikomi, 2008).

Biotic indices (%EPT, BMWP and ASPT) results revealed consistency in all sampling locations A, B, C, and D except %EPT which indicated poor water quality throughout the sampling locations in terms of water quality (Table 3). The %EPT (Ephemeroptera, Plecoptera and Triocoptera) index revealed non-score due to their absence at all the sampling locations. The absence of these species in the sampling locations is an indication of gross pollution due to anthropogenic activities at the locations, since many studies have reported higher abundance and diversity of this group of macroinvertebrates to clean and pollution-free water bodies (Arimoro and Ikomi 2008; Odume *et al.* 2012). In addition, some taxa of EPT are the best indicators of agricultural impacted and show strong preference for a rocky substratum and marginal vegetation (Selvakumar *et al.* 2014). The result of %EPT index observed in this study is in agreement with the work of Wahizatul *et al.* (2006) who find human activities such as farming and recreation been directly linked to declines in the species richness of aquatic insect groups in the Sekayu stream. The BMWP' index seems to be the most suitable because it takes into account the sensitivity (tolerance) of all the taxa existing in a water body. According to Sellam *et al.,* (2019), this index therefore seems better suited to the arid and semi-arid regions, which do not house the taxa most sensitive to pollution, such as Plecoptera. However, Biological Monitoring Working Party (BMWP) indicated that sampling location A has good water quality with high BMWP score while other sampling locations (B, C and D) are moderately polluted with low BMWP score (Table 3). The Average Score Per Taxon (ASPT) represents the average tolerant score of all taxa within the aquatic ecosystem. A high ASPT usually characterizes clean site with relatively large number of high scoring taxa (Barman and Gupta, 2015). Values calculated in this respect for the macroinvertebrates families recorded in this research indicated excellent clean water conditions for Kandola Shella (UDUS stream).

Shannon-Weiner diversity index measures the number of species and the number of individuals in each species and simultaneously takes into account how evenly the basic species (such as individuals) are distributed among those taxa. A healthy benthic macro-invertebrate community should have a higher Shannon-Weiner diversity index. In this present study, the species diversity indices of macroinvertebrates are presented in Table 3. The highest Shannon diversity index was documented in sampling location C and the lowest in location A respectively. The result obtained in the current study differs greatly from those recorded in the assessment of the health status of some rivers, streams, lakes and ponds; Andem *et al.* (2015), Olomukoro and Dirisu (2014) and Ghosh and Biswas (2017). The characteristic differences in the fauna of the aquatic populations from these studies were the leading factor for the bias recorded in the Kandolla Shella Stream (UDUS stream). The Evenness index measures the evenness or equitability of the community by scaling one of the heterogeneity measures relative to its maximal value that each species in the sample is represented by the same number of individuals (Brraich and Kaur 2017).

The evenness value (Shannon's equitability) was noted as low in all locations, representing a relatively even distribution of species in the Kandolla Shella stream (UDUS stream). The species diversity and evenness were maximum in nearly all the locations representing good quality of water. In the present study, the species diversity index was always greater than one. The dominance obtained the lowest value at sampling location A and the highest was observed at location C respectively. Higher evenness index values supporting high equitability of benthic macroinvertebrates have also been reported by Basu *et al.* (2013) at East Calcutta Wetlands. This is also in agreement with the study by Brraich and Kaur (2017) who observed an even distribution of benthic macroinvertebrates species in his studied habitat.

CONCLUSION

The results obtained from the study established that, the absence of EPT taxa of macroinvertebrates from the samples collected and the presence of pollution-tolerant group as well as low Shannon Weiner index of diversity are conclusive evidence that anthropogenic activities (agricultural practices) around Kandola Shella stream (UDUS stream) indicate minimal to high organic pollution of some locations. Overall, Kandola Shella stream (UDUS stream) was described as slightly polluted due to minimal and organic pollutant concentration at various locations.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

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