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Response of Macroinvertebrates Functional Feeding Groups to Agricultural Activities in a Rural River in North-Central Nigeria

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Abstract

Freshwater bodies are being contaminated by the growing human population in many developing nations and one of the major contamination source is agricultural activities within the land used catchment. In this study the response of macroinvertebrates functional feeding group in response to agricultural activities in River Wanzum Niger state Nigeria was investigated. Four (4) sites were sampled base on anthropogenic impact in the river for a period of 24months (December 2021- November 2023). From the result of the physicochemical parameters measured, only turbidity and dissolved oxygen showed significant difference ($p<0.05$) between the sampling sites. All the physicochemical parameters measured in this study differs significantly ($p<0.05$) among the sampling months. A total of 2, 863 macroinvertebrates belonging to 33 families were identified. The family notonectidae was the most dominant taxa and the least dominant taxa were Teleganonidae and Hirudinidae. The macroinvertebrates were classified into shredders, collector-gatherers, collector-filterer, scraper and predators functional feeding group. There was significant difference ($p<0.05$) in abundance of the FFG as predators account for 72% abundance followed by scrappers 12%, collector-gatherer 8%, shredders 5% and the least FFG were the collector-filterer with 3% abundance in all the sampled sites. The CCA ordination plot has an eigen value of 0.047and 0.012 with 78.44% and 21.33% variance in dataset. The correlation between the functional feeding group and the physicochemical shows the shredders, collector-gatherer and collector-filterer were associated with site 1 and 4 which are the less perturbed station and were influenced by pH and dissolved oxygen. The scrapers were positively associated with CCA axis 2 which was influenced by temperature, depth, pH and nitrate in site 3 and the predators

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were negatively associated with CCA axis 2. Overall, this study shows that predators population increased with increased agricultural activities around river Wanzum.

Keywords. Freshwater, Macroinvertebrates, Functional feeding group, Agricultural activities, River Wanzum.

INTRODUCTION

Freshwater bodies are being contaminated by the growing human population in many developing nations, along with poor management techniques, which calls for immediate care (Addo-Bediako 2021). As a result of their detrimental effects on aquatic creatures and the degradation of river systems, the effluents or waste from various anthropogenic activities in the catchment of water bodies pose a hazard to the system (Jun *et al.,* 2016). One of the simplest and most affordable ways to determine how human activity affects the freshwater ecosystem's water quality is through biomonitoring. According to Merritt *et al.,* (2017), biomonitoring is a more beneficial method of obtaining ecological information about rivers than physicochemical indicators for monitoring water quality. For example, compared to chemical and microbiological data, which mostly show short-term variation, macroinvertebrates provide a more accurate understanding of changes in aquatic environments (Ghasemi and Kamali 2014). Additionally, macroinvertebrates serve as a crucial functional link between upper trophic levels, like fish, and basic resources, including algae and detritus (Mohammed *et al.,* 2021).

One of the prominent land used around water bodies in most part of the world is agricultural activities. In Nigeria agricultural activities is the major land use practice closed to water bodies (Mohammed *et al.,* 2020; Edegbene *et al.,* 2022). Agricultural activities can have a variety of effects on freshwater ecosystems due to associated nutrient and organic input (Zhang et al., 2021), which have effect like changes in flow-regime and degradation of riparian and in-stream habitats (Cornejo *et al.,* 2020), abstraction of water for irrigation and natural forest removal (Horak et al., 2020). In particular, agricultural activities in the surrounding landscape of freshwater ecosystems have been implicated as the leading anthropic activities altering abiotic and biotic characteristics of freshwater ecosystems (Mohammed *et al.,* 2023) and these disturbances as a whole lower water quality, change the physical habitat, and simplify aquatic communities, which leads to the loss or replacement of sensitive taxa by tolerant taxa and a decrease in biodiversity (Akamagwuna *et al.,* 2020). For instance, as agricultural and urban land use in watersheds grow, a significant volume of household and some industrial wastewater is released into urban rivers (Cornejo *et al.,* 2020). To better comprehend the current state of fresh water systems and forecast their ecological integrity in the future, it is imperative to increase our understanding of the specific effects of agriculture on Afrotropical stream functioning, which is currently lacking.

Ecologists seek to comprehend how changes in land use affect biodiversity in this context and investigate which evaluation techniques can reliably look at the answers. In comparison to other aquatic indicators, macroinvertebrates have several advantages, including sensitivity to stream disturbance, short life cycles, limited mobility, and ease of collection and identification (Arimoro and Keke, 2016). Macroinvertebrates are valuable and excellent indicators for biomonitoring and bioassessment (Bonada et al. 2006). In the setting of rising concentrations of agricultural and urban contaminants, macroinvertebrates might potentially signal habitat degradation and fragmentation brought on by changes in land use (Mohammed *et al.,* 2021; Adamu *et al.,* 2022). The use of macroinvertebrate functional feeding group (FFGs) has grown in the evaluation of the ecological integrity of freshwater ecosystems, since they offer valuable information for research on pollution (Varadinova and Kerakova, 2018). On the other hand, the few studies that have been conducted on this topic have yielded inconsistent results, leaving us with a lack of clear information about macroinvertebrate FFGs reactions to agricultural disturbance in tropical climates on the African continent (Akamagwuna *et al.,* 2020; Sitati et al., 2021; Edegbene *et al.,* 2022). Functional feeding groups delineate the behavioural and physiological strategies employed by macroinvertebrates to acquire food and utilise their habitat in varying environmental situations (Cummins and Klug 1979; Wallace and Merritt (1980). In the current study, we explored the use of functional feeding group that has been adjudged to aid in the detection of continuous level of degradation in river systems (Edegbene et al., 2022, Addo-Bediako 2021). Therefore, in the current study we used the functional feeding group for the evaluation assessment of the ecological status of River Wanzum in north central Nigeria.

MATERIALS AND METHODS.

Description of the study area.

River Wanzum is located in floodplains of Lavun Local Government area of Niger State, Nigeria. The river is within the vegetation belt of guinea savannah of North-central Nigeria. The mean annual temperature and relative humidity of the study area are 30.2 °C and 61%, respectively while and the mean annual rainfall ranged between 1200mm and 1300 mm (Edegbene *et al.,* 2023). The study area is characterized by two seasons (wet and dry), the wet season is between April and November and dry season spans from December to March (Mohammed *et al.,* 2023). The major anthropogenic activities in River Wanzum and around its catchment's area include washing, car wash, indiscriminate fishing, and unregulated farming and irrigation activities. River Wanzum also serves as potential potable water source for the neighboring communities.

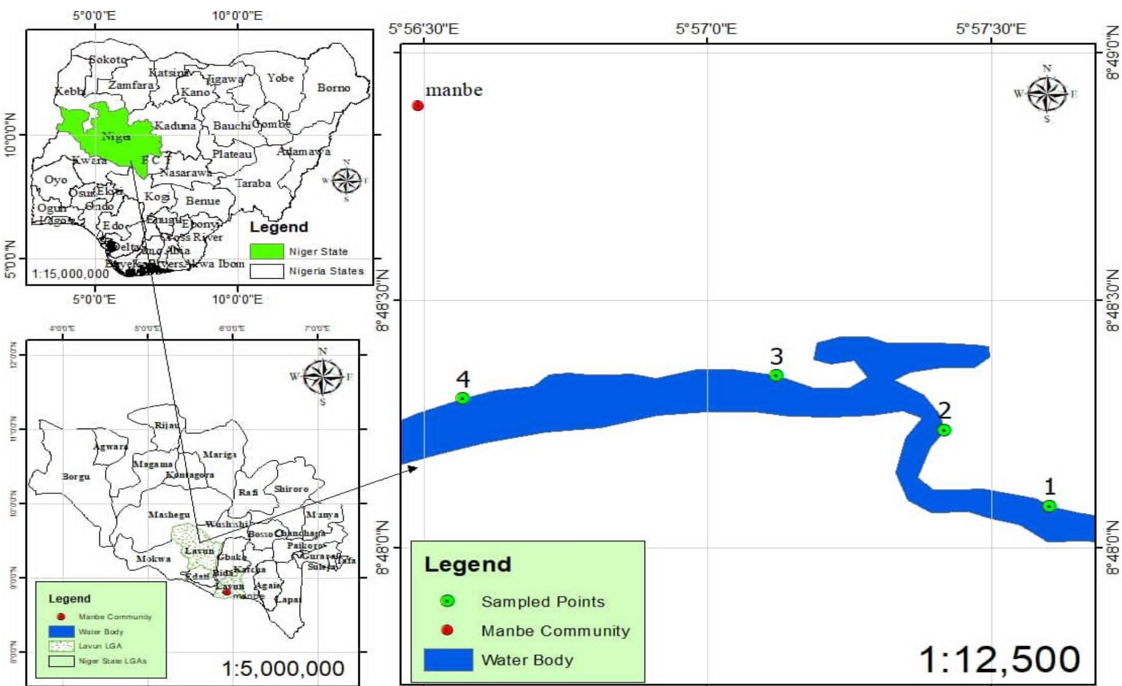

Figure 1: Map showing the four sampled stations of Wanzum River, Manbe Niger State Nigeria.

Sampling sites

We marked out four designated sampling sites based on different level of anthropogenic activities along the course of the river. Sampling site 1 is Kponkparagi, was marked as the reference site for the purpose of this study and it is characterized by few anthropogenic activities when compared to the remaining three sampling sites which are impacted with various degree of anthropogenic activities. Site 2 Mindu, is characterized with numerous anthropogenic activities like washing of clothes and household utensils by the women, car wash, fishing and irrigation of water to farms at the bank of the river. Sometimes sand dredging also been carried out at this station. Sampling site 3 is Wanzum-Tachin, this site is one of the prominent landing sites for fishermen and the site is characterized with numerous anthropogenic activities like bathing washing of clothes, car wash, fishing and irrigation of water to farms at the bank of the river. Site 4 is Edzwan-biye and it is the quiet and encloses section of the River and the only human activity occuring in this site is fishing. We carried out the study for a period of 24 months (December 2021- November 2023) and samples of aquatic macroinvertebrates were collected across all the sampling sites on monthly basis.

Physicochemical parameters determination and macroinvertebrates sampling analysis
In this study, water temperature, depth, flow velocity, turbidity, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), phosphate and nitrate were measured. Water temperature was measured using a mercury-in-glass thermometer, while a multifunctional meter (HANNA HI 9828) was used to test for DO, BOD_5 turbidity and pH. Flow velocity was determined by timing a float as it traveled ten meters in three repetitions. Water depth was measured using a measuring rod. Water samples were taken in 1-liter sample bottles and examined for BOD_5, total hardness, phosphate, and nitrate following the American public health association (APHA 1998) procedures.

Samples of macroinvertebrates were collected using the modified kick sampling technique for a period of 3-minutes per biotope. Kick sample of macroinvertebrates were collected with the aid of 500 µm mesh size D-frame net along a stretch of 25m wadeable section of each sampling site of the river. Samples were taking from diverse macro-habitat and flow regime of each sampling site and the macroinvertebrates collected from each site different habitat were pooled into a single composite sample. Preliminary sorting was carried out immediately after sampling on the field by emptying all collected aquatic macroinvertebrate samples per site onto a white plastic tray and the movable organisms were transferred out with the aid of forceps to a 70% formalin-filled sample bottle. Sampled were taken to Biology Laboratory of Ibrahim Badamosi Babangida University, Lapai, Niger State, Nigeria for final identification using available identification keys guides in Nigeria (Arimoro & James, 2008; Umar *et al.,* 2013) and in Africa (Gerber and Gabriel, 2002; Day *et al.,* 2002; De Moor *et al.,* 2003). The functional feeding group of this study was classified base on the reports of (Merritt and Cummins, 1996; Cummins *et al.,* 2005; Merritt *et al.,* 2008) and each macroinvertebrate taxon was placed into one of five FFG classes, including shredders, collector-gatherers, collector-filterer, scraper and predators.

Data analysis
We calculated the physicochemical parameters variables of the study sites using mean and standard error and two-way ANOVAs were used to compare physicochemical parameters between the sampling sites and the sampling months. Diversity indices such as number of individual, number of taxa, dominance, evenness and Margalef index were calculated using the diversity function of PAST (paleontological statistical software). The relationship between macroinvertebrate FFGs and physicochemical parameters across the four sampling sites were determined using the Canonical correspondence analysis (CCA) and Monte-Carlo

permutation test was further used to confirm the level of significance of the FFGs between sampling sites. All data were analyzed using the software package PAST v4.03

RESULTS

Physicochemical parameters of the sampling sites of river Wanzum Manbe Niger State Nigeria

Table 1 shows the physicochemical parameters of all the sampled site of River Wanzum. Water temperature ranged from 23.99±0.42°C in site 4 to 24.90±0.50°C in site 3. Water depth ranged from 49.50±4.78cm in site 2 to 57.16±4.52cm in site 3. Flow velocity value ranged from 0.07±0.01m/s in site 1 to 0.10±0.01 site 3. Turbidity ranged between 124.75±1.37 NTU in site 4 to 141.33±3.75 NTU in site 2. Water pH ranged from 6.83±0.10 in site 2 to 7.01±0.11 in site 4. Dissolved oxygen ranged from 5.80±0.91mg/L in site 3 to 6.45±0.12 mg/L in site 4. Biochemical oxygen demand ranged from 3.70±0.18 mg/L in site 3 to 4.22±0.30 mg/L in site 2. Nitrate ranged from 0.98±0.23mg/L in site 2 to 1.17±0.28 mg/L in site 3 and phosphate ranged from 0.33±0.09 mg/L in site 1 to 0.55±0.13 mg/L in site 4. Of all the physicochemical parameters measured, only turbidity and dissolved oxygen showed significant difference ($p<0.05$) between the sampling sites. All the physicochemical parameters measured in this study differs significantly ($p<0.05$) among the sampling months.

Table 1: physicochemical parameters of the sampled site of River Wanzum Manbe Niger State Nigeria.

Parameter	Stations				P-value	
	Site 1	Site 2	Site 3	Site 4	Stations	Months
Water temperature (°C)	24.5±0.55	24.25±0.44	24.90±0.50	23.99±0.42	0.592	2.70E-05
Depth (cm)	51.07±5.04	49.50±4.78	57.16±4.52	50.57±4.78	0.668	1.85E-19
Flow velocity (m/s)	0.07±0.01	0.09±0.01	0.10±0.01	0.09±0.01	0.33	7.01E-06
Turbidity (NTU)	130.55±2.24	141.33±3.75	138.33±2.63	124.75±1.37*	0.003	0.027
pH	6.99±0.13	6.83±0.10	6.90±0.12	7.01±0.11	0.5935	3.86E-09
Dissolved oxygen (mg/L)	6.39±0.35	6.36±0.24	5.80±0.19*	6.45±0.12	0.003	0.309
Biochemical oxygen demand (mg/L)	3.75±0.25	4.22±0.30	3.70±0.18	4.02±0.16	0.686	0.028
Nitrate (mg/L)	1.06±0.25	0.98±0.23	1.17±0.28	1.14±0.27	0.982	2.90E-05
Phosphate (mg/L)	0.33±0.09	0.45±0.13	0.48±0.28	0.54±0.13	0.608	3.22E-07

Macroinvertebrates and their functional feeding group in the sampling site of river Wanzum Manbe Niger State Nigeria.

A total of 2, 863 macroinvertebrates belonging to 33 families were found and identified in all the sampling site of River Wanzum for a period of 24months (Table 2). Notonectidae was the most dominant taxa in all the sampled site followed by Corixidae and the lest dominant taxa were Teleganonidae and Hirudinidae which were represented by 1 individuals each through out the sampling period (Table 2). Figure 2 shows the percentage abundance of Macroinvertebrates FFG in studied River. There was significant difference ($p<0.05$) between the functional feeding groups abundance in this study as predators account for 72%

abundance followed by scrappers 12%, collector-gatherer 8%, shredders 5% and the least FFG were the collector-filterer with 3% abundance in all the sampled sites. In term of relative abundance predators were the most abundant dominant FFG in all the sampled site of the river while the collector-filterer were the least abundance and dominant group in all the sampled site of the river (Figure 3).

The diversity indices of macroinvertebrate families in the sampling sites of river Wanzum is presented in Table 3. Sampling site 1 and 4 record highest in term of number families/ taxa while the site 2 and 3 record the lowest (23) taxa. Site 1 had the highest number of organisms, followed site 3 and 4 while site 2 had the lowest with 643 organisms. Site 2 was more dominance followed by site 3, while site 1 had the lowest dominance. In term of evenness, site 1 was more even followed by site 2 while site 3 record the lowest evenness. Margalef index record highest in site 4 (3.54) and record lowest in site 3 (3.27).

Table 2 Families of macroinvertebrates and their assemblage in the sampled site of River Wanzum Manbe Niger State Nigeria.

Family	Site 1	Site 2	Site 3	Site 4	Functional feeding group
Nepidae	17	19	26	15	Predators
Notonectidae	246	260	239	234	Predators
Vilidae	0	0	6	4	Predators
Belostomatidae	14	33	20	17	Predators
Corixidae	115	46	148	59	Predators/scrappers
Naucoridae	9	26	19	13	Predators
Gerridae	1	0	3	2	Predators
Hydrometridae	2	4	0	3	Predators
Coenagrionidae	56	39	32	99	Predators
Gomphidae	1	16	4	0	Predators
Libeluubidae	33	19	15	12	Predators
Lestidae	5	2	0	0	Predators
Hydrochidae	13	0	0	0	Collector-gatherers
Gyrinidae	0	2	0	0	Predators
Staphlinidae	5	2	0	1	Predators
Dysticidae	66	48	104	53	Predators
Hydrophilidae	74	49	31	28	Predators
Chrysomelidae	0	1	5	0	Scrapper
Baetidae	19	5	5	15	Shredders/Collector-Gatherer
Teleganonidae	0	0	0	1	Scrapper
Leptophelidae	37	9	2	14	Shredders/Collector-Gatherer
Hydropsychidae	5	0	4	1	Shredders/Collector-filterer
Ecnomidae	0	0	0	1	Collector-filterer
Pisauridae	31	26	15	33	Predator
Chironomidae	24	7	13	23	Shredders/Collector-Gatherer
Culicidae	0	0	1	3	Collector-Filterer
Tibulidae	1	0	0	0	Collector-Gatherer
Cereptogonidae	0	0	0	1	Predator

Atydae	49	12	11	27	Collector-Gatherer/ Filterer	Collector-
Hirudinidae	0	1	0	0	Predator	
Thiaridae	0	3	3	0	Scraper	
Planobidae	5	14	14	4	Scraper	
Unionidae	1	0	2	0	Predator	
	829	643	728	663		

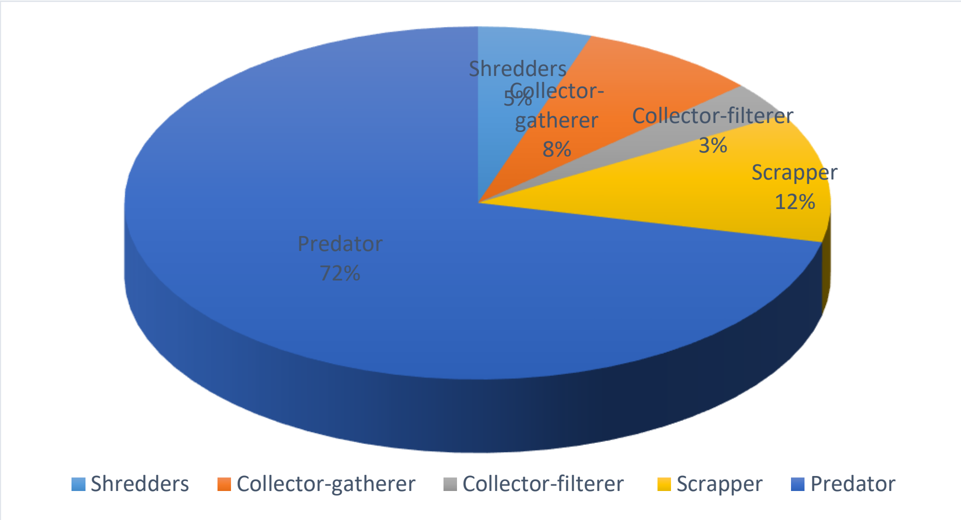

Figure 2: Percentage abundance of Macroinvertebrates functional feeding group in River Wanzum Manbe Niger State Nigeria.

Table 3: Diversity indices of macroinvertebrates families in River Wanzum Manbe Niger State Nigeria.

Indices	Site 1	Site 2	Site 3	Site 4
Taxa_S	24	23	23	24
Individuals	829	643	728	663
Dominance_D	0.137	0.193	0.186	0.171
Evenness_e^H/S	0.465	0.417	0.3594	0.404
Margalef	3.423	3.402	3.274	3.54

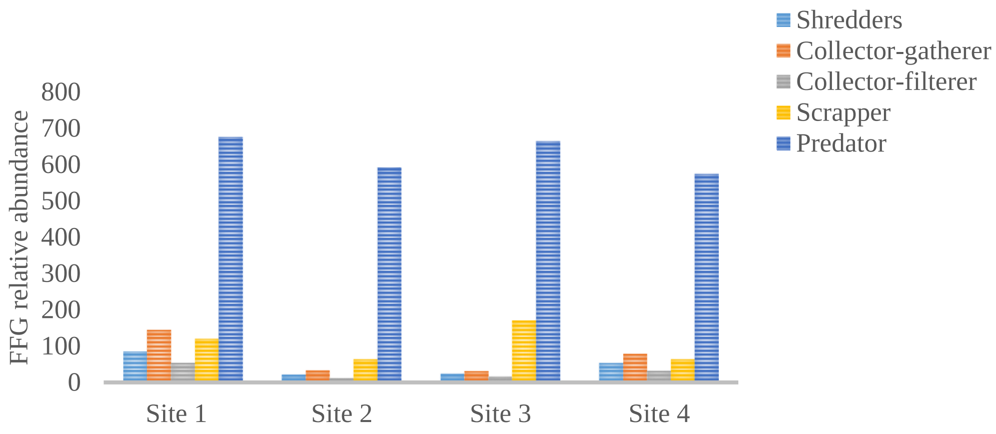

Figure 3: Relative abundance of macroinvertebrate functional feeding groups collected in River Wanzum Manbe Niger State Nigeria during the study period.

Macroinvertebrate FFG responses to agricultural activities in River Wanzum Manbe Niger State Nigeria.

The CCA result showed a spatial macroinvertebrates functional feeding group association with the measured physicochemical parameters (Fig 3) and the first two axes of the CCA with eigen value of 0.047and 0.012 with 78.44% and 21.33% variance in dataset (Table 4). The correlation between the functional feeding group and the physicochemical shows the shredders, collector-gatherer and collector-filterer were associated with site 1 and four which are the less perturbed station in CCA axis 1 and 2 which were influence by pH and dissolved oxygen while the scrapers positively associated with CCA axis 2 which was influenced by temperature, depth, pH and nitrate in site 3 the predators were negatively associated with CCA axis 2.

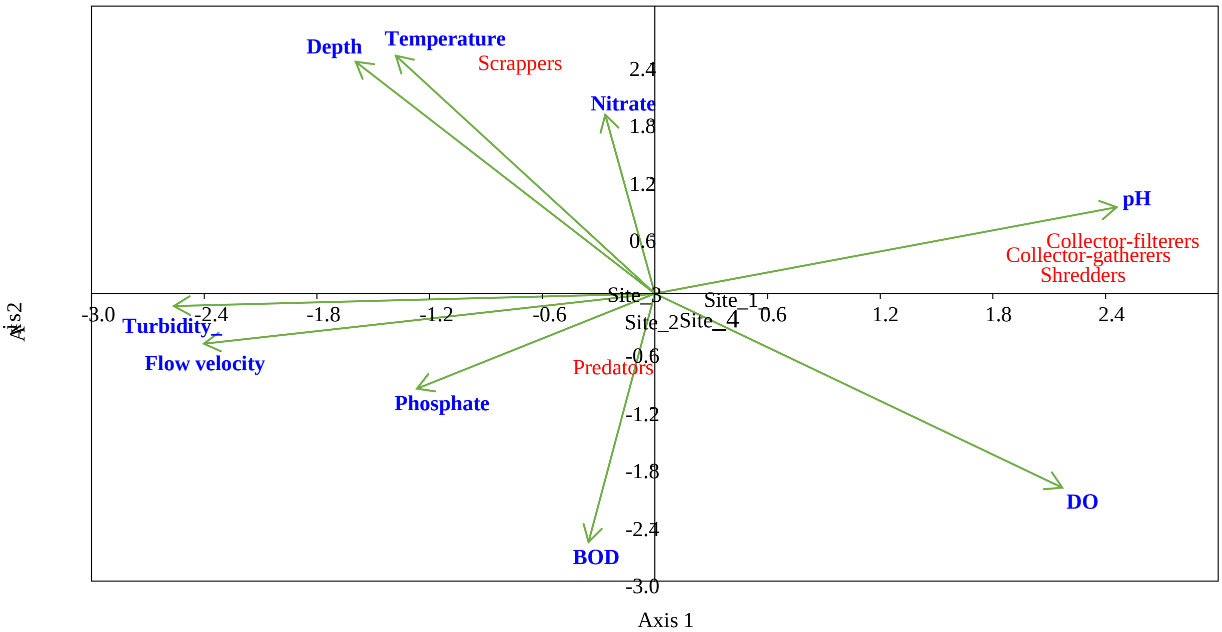

Fig 3: Canonical correspondence analysis (CCA) ordination plot showing the relationship the sampling sites, functional feeding group and the measure physicochemical parameters.

Table 4; Canonical correspondence analysis (CCA) result for the relationships between analysed physicochemical parameters and macroinvertebrate functional feeding groups (FFGs) in River Wanzum Manbe, Niger State Nigeria

Axis	Eigenvalue	%
1	0.047	78.44
2	0.012	21.33
Cumulative values	0.059	99.77

DISCUSSION

Rainfall and the drainage basin's pattern typically have an impact on the water level of the aquatic ecosystem (Emere and Nasiru, 2009). As previously reported in other studies conducted in Nigeria (Arazu and Ogbeibu, 2017; Mohammed *et al.,* 2020; Mohammed *et al.,* 2021; Edegbene *et al.,* 2022; Adamu *et al.,* 2022; Maishanu *et al.,* 2022; Ebesi *et al.,* 2022; Adama *et al.,* 2023), the majority of the physicochemical values recorded during this study indicates a typical tropical climate environment. The average temperature of the water varied between 23.99±0.42°C and 24.90±0.50°C. Given that it controls the physiological behaviour of aquatic organisms and their dispersion, temperature is one of the most crucial factors in aquatic ecology (Mustapha, 2008). The study found that the water temperature was moderate, which may have been caused by the vegetation surrounding the water body and the time the samples were taken.

The increased pH and turbidity level of the water in the current study indicated that the river has been continuously influenced by anthropogenic influences. Other studies have linked the deterioration of rivers and streams to increased agricultural activity along their reaches and catchments (Edegbene *et al.,* 2022). The findings of these studies reflects that the river surroundings are used for farming activities as farmers get water from the river for irrigation and other agricultural activities. The study further asserted that elevated values of pollution indicating physicochemical variables posed a severe ecological risk to assemblage of most aquatic organisms in aquatic environment especially the macroinvertebrates (Omovoh *et al.,* 2022). On the other hand, DO concentration was low in all the sampled sites while BOD_5 was high in all the sites indicating that the sampling sites were perturbed. Both DO and BOD_5 has been consistently used as a benchmark to measure relatively unperturbed and pertubed sites across the globe (Mustapha, 2008; Omovoh *et al.,* 2022; Garba *et al.,* 2022). The high nutrient level (nitrate and phosphate) in the river could be attributed to the variety of human activities, including farming on the river bank, surface runoff and organic matter decomposition (Ibrahim *et al.,* 2009; Mohammed *et al.,* 2021), as northern Nigeria is characterized with extensive commercial farming activities through the year. The majority of farmers in the area cultivate their crops with fertilizer and other chemicals. Furthermore, the observed low water quality of the river may be attributed to unregulated anthropogenic disturbance on the River as a result of lack of management and proper enforcement of regulations governing Nigeria's water bodies.

There was variations in the compositions of macroinvertebrates among the sampling locations, which could account for the observed pattern of distribution. The increased intake of organic nutrients from agricultural operations along River Wanzum may be the cause of the high macroinvertebrate abundance at sampling site 1, although significant human disturbance was seen during the sample period, sampling sites 2 and 3 exhibited the lowest taxonomic richness in terms of number on individual. It is possible that these sites benefited certain tolerant taxa (Cortes *et al.,* 2013; Addo-bediako, 2021). This finding corroborate with the report of Elias *et al.*, (2014) and Addo-bediako (2021) who are of the view that macroinvertebrate communities at degraded sites are typified by a larger dominance of a small number of tolerant species and the absence or presence of select sensitive taxa. The low abundance of pollution sensitive taxa such as such as Baetidae, Teleganonidae, Leptophelidae and Hydropsychidae in site 2 and 3 is an indication that the high agricultural land used close to the sampling sites has effect on their assemblage as they are deem sensitive to pollution and are among the first groups of macroinvertebrates families to disappear when aquatic habitat is experiencing changes due to certain human interference (Garba *et al.,* 2022). Agricultural activities or land used cover has been reported to favor pollution-tolerant species in most part of the world (Edegbene *et al.,* 2023; Mohammed *et al.,* 2023). Their food supplies' availability and the environmental diversity at these sites can be used to explain why the FFG varied at different sampling sites. Barbour *et al.* (1996) state that whilst generalist feeders, such collector-gatherers and collector-filterers, are more resilient to pollution that may change the availability of specific food, specialised feeders, like shredders and scrapers, are thought to be more susceptible to disturbance. Masese *et al.,* (2014) revealed that in highland streams in Kenya, collectors dominated the whole river. When compared to the predators in each of the sampling sites, we found that the populations of collector-gatherers, collector-filterers, shredders, and scrapers were significantly lower. This suggests that indiscriminate agricultural activities along the river have caused human interference with the riparian vegetation. Leaf fall in rivers may be caused by the lack of canopy cover at the sampling station, which could also be the reason for the low number of shredders in all of the river's sampled sites. In aquatic habitat, the dispersal of shredders is favoured by canopy cover (Addo-bediako *et al.,* 2021). Moreover, effective microbial activities may take the role of shredder activity in high-temperature tropical African rivers, explaining the low abundance of functional groups like shredders (Deemool and Prommi 2015). This function differs from that of rivers in temperate regions. In some river sampling sites, anthropogenic activities including farming, washing, and dredging of sand may have resulted in a reduction or loss of riparian vegetation, which could account for the low numbers of collector-gatherers, collector filterers, and scrapers.

Additionally, most of the taxa in this study exhibit predatory traits. This could be because they have specialized respiratory organs, such as spiracles and trachea, for taking in atmospheric oxygen, which allows them to adapt to the river's decreasing DO level. Consequently, they have a significant association with agricultural activities in rivers like Wanzum. Edegbene *et al*., (2022) examine how the use of urban agricultural land affects the functional feeding groups of macroinvertebrates and discover that both land uses considerably support the abundance of predators. Furthermore, predator abundance considerably increased in disturbed sites according to Fu *et al.,* (2016), who studied the impact of landuse practices on physical and chemical properties as well as macroinvertebrate FFGs in the Dongjiang River, southeast China. Together with our data from River Wanzum, the results of the previously mentioned studies provide credence to the idea that a declining aquatic ecosystem's functional feeding group's abundance is a sign of declining water quality.

CONCLUSION

This study shows the abundance of different feeding group across all the sampled site of the river and how they respond to agricultural activities. Macroinvertebrate FFGs such as shredders collector-filterers, collector-gatherers and scrappers were low in abundance across all the sampled sites as predators dominated all the sampled stations. Most of the observed

FFGs were positively associated with some physicochemical parameters measured. This finding roved that agricultural activities in the river has adverse effect on the deteriorating water quality and the biodiversity and functioning of the river. Finally, The FFG pattern of the Wanzum River shows the effect of changing environmental conditions on macroinvertebrates along the river and therefore confirm that FFG is an effective tool to assess ecological integrity of rivers.

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