The University of Tehran Press

Pollution

Print ISSN: 2383-451X
Online ISSN: 2383-4501

https://jpoll.ut.ac.ir/

Assessing the Ecological Integrity of a Rural River using Macroinvertebrate Diversity and their Functional Feeding Groups in North-Central Nigeria

Kabir Mohammed Adamu[1] | Yakubu Manbe Mohammed[1]✉ | Aisha Ndajiya Mohammed[1] | Hafsat Muhammad Oladunni[1] | Eunice Ojoma Ikayaja[2]

1. Department of Biology, Faculty of Natural Sciences, Ibrahim Badamasi Babangida University Lapai, Niger State, Nigeria.
2. Ecology and Environmental Biology Unit, Animal Biology Department, School of Life Sciences, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.

Article Info

Article type:
Research Article

Article history:
Received: 4 March 2025
Revised: 23 June 2025
Accepted: 3 September 2025

Keywords:
Tayagi River
Biomonitoring
Freshwater
Macroinvertebrates
Functional feeding group

ABSTRACT

Globally, freshwater is one of the most threatened habitats. Anthropogenic activities exert a significant pressure on this unique natural resource leading to decline in water quality and loss of biodiversity. Therefore, the need to evaluate the health status of rivers and the possible threats they are facing in order to protect and manage their resources adequately. In this study we used physicochemical parameters, macroinvertebrate assemblages and their functional feeding groups to ascertain the health status of a rural river. Samples were collected from three stations based on their levels of anthropogenic activities Mean values of total alkalinity, total hardness, BOD5, phosphate and nitrate were highest in station 1 and lowest values were observed in station 3 except for BOD5 and nitrate which recorded lowest mean values in station 2. All recorded physicochemical parameters showed no significant ($p>0.05$) difference across the sampled stations, while significant ($p<0.05$) among the sampling months except temperature, flow velocity, pH and BOD5. A total of 136 individuals macroinvertebrates belonging to 10 species in three functional feeding groups (FFG) were identified. Predators accounted for 82%, Scrapers 16% and 2% were collector-gatherers. The Canonical correspondence analysis (CCA) axis 1 accounted for 64.93% of the species variation while CCA axis 2 accounted for 35.07% of the species variation with eigen value of less than1 indicating weak or no relationship. Overall, this study revealed that macroinvertebrate assemblages and their functional feeding group are good indicators of aquatic ecological integrity. This provided further insights into the impact of anthropogenic activities on freshwater systems and using macroinvertebrate functional feeding groups as best indicators of ecosystem health.

Cite this article: Adamu, K.M., Mohammed, Y.M., Mohammed, A.N., Oladunni, H.M., & Ikayaja, E.O. (2025). Assessing the Ecological Integrity of a Rural River using Macroinvertebrate Diversity and their Functional Feeding Groups in North-Central Nigeria. *Pollution*. 11(4), 1371-1383.
https://doi.org/10.22059/poll.2025.392106.2841

DOI: https://doi.org/10.22059/poll.2025.392106.2841

INTRODUCTION

Freshwater provides clean drinking water, industrial water use, water for irrigation, recreation, generation of electricity, transportation, and habitat for plants and animals which are of economically important to the society (Magbanua et al., 2023). Regretfully, the world's freshwater ecosystems are suffering from a number of stresses linked to the increase in human population, the exploitation of natural resources, changes in climate and land use type (Namba et al., 2020; Feio et al., 2023). Pollutions from various human activities such as indiscriminate mining, unregulated agricultural activities and increase in population growth have continuously led to degradation in water bodies. Worldwide, freshwater ecosystems face escalating surface water pollutants, with many threats by humans to biodiversity, climate change, infectious

*Corresponding Author Email: *yakubmohammedmanbe@yahoo.com*

diseases, harmful algal blooms, emerging contaminants, microplastics, and lot more. These pollutant or contaminants are detrimental to the functioning freshwater biodiversity and ecosystem (Arimoro & Keke, 2017; Dudgeon, 2019; Reid et al., 2019). Vulnerable rivers are affected and prone to cumulative risks from climate and land use changes such as urbanization, agricultural intensification, and mining. Providing safe drinking water, cutting pollution, conserving water, preserving ecosystems, and aiding poor nations with water projects are some of the main goals of Sustainable Development Goals (SDGs). Pollution and water scarcity continue to be important global issues.

Macroinvertebrates are diverse groups of organisms which respond to both natural and man-made environmental changes in aquatic environments (Akindele & Liadi, 2014; Arimoro & Keke 2017; Namba et al., 2020; Adamu et al., 2022). River systems are being deteriorated and biotic species are being threatened by anthropogenic effluents from river catchments (Jun et al., 2016; Addo-Bediako et al., 2020). According to Emere and Nasiru (2009), most streams in Nigeria are subjected to a growing amount of pollution from tainted urban runoff water that comes from the commercial, industrial, residential, agricultural, and recreational sectors as well as establishments like schools and hospitals.

Biological monitoring is one of the ways for detecting the effect of human activities on the health status of aquatic environments. It is regarded to be more effective than physicochemical parameters as it utilizes living organisms which are easy to collect and asses to ascertain ecological health of freshwater environments (Akindele & Liadi, 2014). Biological indicators such as fish, macrophytes, macroinvertebrate and plankton respond swiftly to pollution (Edegbene et al., 2023). Thus, macroinvertebrates are particularly valuable for acquiring river biological information (Mohammed et al., 2020; Adamu et al., 2022). Ghasemi and Kamali (2014) reported that macroinvertebrates give more detailed comprehension of changes in aquatic environments when compared to physicochemical and microbiological indicators. Macroinvertebrates are the most widely used species for biological monitoring of freshwater habitats globally. Macroinvertebrate are found in the majority of habitats, have generally limited mobility, are fairly simple to collect using diverse methods of sampling, and are composed of a variety of forms that entail different range of sensitivities to changes in water quality (Namba et al., 2020; Mohammed et al., 2021). Macroinvertebrate species composition, their feeding behaviours and methods for consuming food supplies determine their ecological functions within an ecosystem (Ramírez & Gutiérrez-Fonseca, 2014). One benefit of using functional feeding groups (FFGs) is that it combines the morphological traits (mouth part specialisation) and behavioural mechanisms (feeding strategy) that macroinvertebrates utilise to obtain food (Cummins & Klug, 1979).

Tayagi River provides water for consumption, bathing, irrigation and processing of farm produce. With the increasing human population around Agaie Metropolis, there is increase in anthropogenic activities such as indiscriminate defecation, unregulated farming in river bank, washing of household utensils and laundry. The primary objective of this study is to conduct a comprehensive assessment of the ecological integrity of a Tayagi River using macroinvertebrate diversity and their functional feeding groups. Also to establish a baseline assessment of ecological integrity within the study area by examining the changes in macroinvertebrate community and water quality, this investigation aims to provide critical insights into the ecological health and resilience of this vulnerable ecosystem. Hence, the current study will serve as a baseline study and also add to the existing literature of other river systems in North-central Nigeria, thus there is need to ascertain the ecological integrity of the river as insufficient literature exists on the ecological status of this river.

MATERIALS AND METHODS

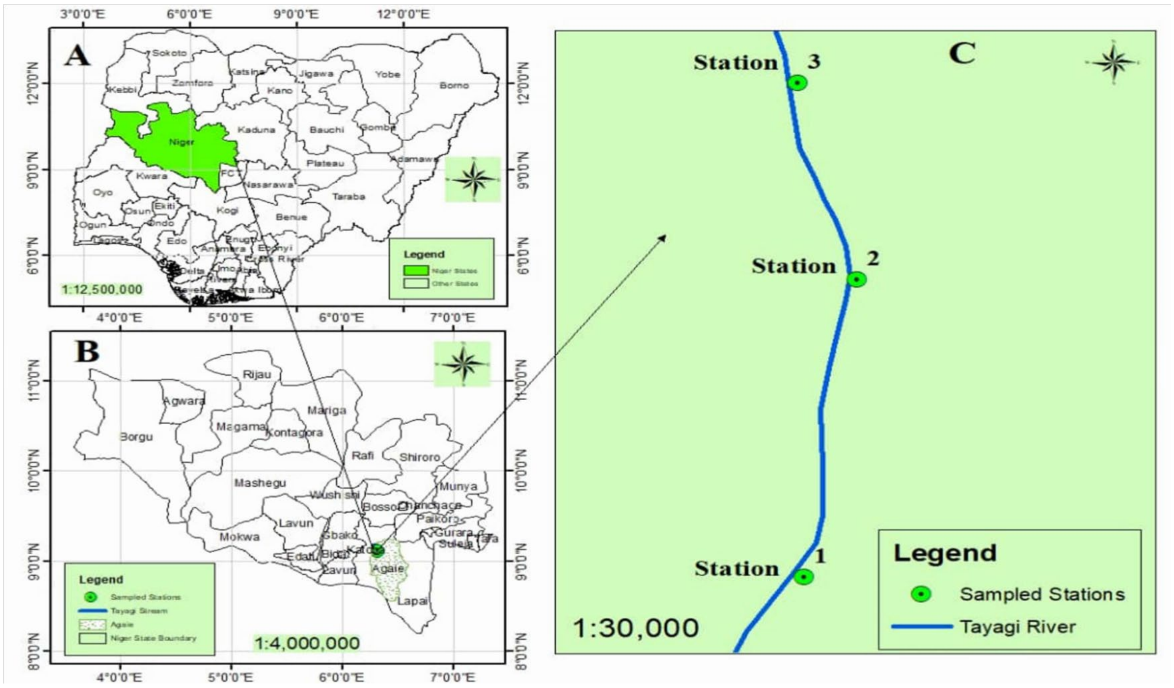

Fig. 1. Map of Niger state showing Agaie local government with Tayagi river indicating the sampling stations

Study area

The research was conducted at the Tayagi River in Agaie 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 the mean annual rainfall ranged between 1200mm and 1300 mm. 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). Tayagi River lies within the interception of latitude of 8°802N to 8°805N and longitude 5°960 to 5°943E of the equator. The major anthropogenic activities in Tayagi River and around its catchment's area include washing of clothes, car wash, indiscriminate refuse dumping, unregulated farming and irrigation activities.

Field sampling and laboratory analysis

Water samples for physicochemical characteristics were collected monthly for a period six months (November 2021 to April 2022) from three (3) selected sampling stations along section of the river. Station 1 which is characterised by less human activities and as a result it tag as the reference station. Station 2 and 3 were characterised by various human activities such as sand mining, bathing, agricultural activities, washing of clothes and kitchen utensils and is classified as the impacted stations as a result of the various human activities carried out around the station. Water samples were collected in a 200ml sampling bottle that had been well cleaned with distilled water prior to field sampling. Prior to laboratory analysis, the samples were placed in a refrigerator (4°C). Water samples were analysed in accordance with the methods of American Public Health Association's guidelines (APHA, 2012). Transparency was determined *in-situ* using a Secchi disc; pH, dissolved oxygen (DO) and electrical conductivity (EC) were determined *in-situ* using a pre-calibrated multipurpose meter (Hannah H1991300/1 model). Similarly, the water temperature of each sampling station was measured *in-situ* with the aid of a mercury-in-glass thermometer (°C). For each sampling station, collected and preserved water samples were used to test the phosphate (PO_4^{3-}), nitrate (NO_3^-), hardness, alkalinity, and Biological Oxygen Demand (BOD_5) according to APHA (2012).

Samples of macroinvertebrates were collected using the modified kick sampling technique (Arimoro & Keke 2017). A modified kick net of 500 µm mesh size was towed against the water current within an approximately 25m wadable section of each sampling site of the river. Samples were taken from diverse macro-habitat and a 250µm hand mesh sieve for diverse micro-habitat from various flow regime of each sampling site and the macroinvertebrates collected from each site 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 10% formalin-filled sample bottle. Samples were taken to the Biology Laboratory of Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria for final identification using available identification keys and guides in Nigeria (Arimoro & James, 2008; Umar et al., 2013) and in Africa (Day et al., 2002; Gerber and Gabriel, 2002; De Moor et al., 2003). We classified the functional feeding group of this study base on the reports of (Merritt & 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-filterers, scraper and predators.

Data analysis

Mean values, standard deviation, and range were calculated for each physical and chemical variable per station. To examine the effects of seasonality and spatial variability on the physicochemical and biological metrics, a two-way analysis of variance with repeated measures (Two-way ANOVA) was employed. Diversity indices such as number of individuals, 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 three (3) sampling stations 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 analysed using the software package PAST v4.03

RESULTS AND DISCUSSION

Physicochemical parameter of Tayagi River Agaie Niger State.

The mean values of the measured physicochemical parameters of the sampling station of Tayagi river, Agaie, Niger state in presented in Table 1. The mean temperature ranges from 26.66±0.70°C in station 3 to 29.36 ±1.67°C in station 2. The mean depth value ranged from 38.88± 8.49C station 1to 53.2±12.23 in station 2. The mean flow velocity value ranged from 0.017 ±0.01m/s at station 2 to 0.029±7.90m/s in station 1. Transparency mean value ranged from 30.73±7.47 in station 1 to 39.03±7.23 cm in station 2. The water pH and electrical conductivity recorded lowest mean value in station 1 (7.02±0.13, 69.16±8.03µ/Sc) and record highest in station 3 (7.08±0.09, 77.66 ±10.763µ/Sc). Mean values of total alkalinity, total hardness, BOD_5, phosphate and nitrate were highest in station 1 and lowest values were observed in station 3 except for BOD_5 and nitrate which record lowest mean values in station 2. All the physicochemical parameters measured shows no significant difference ($p>0.05$) between the sampling stations while all the physicochemical parameters differ significantly ($p<0.05$) among the sampling month except some parameters such as temperature, flow velocity, pH and BOD_5 which showed no significant difference ($p>0.05$) in the sampling months of Tayagi River Agaie Niger State.

According to other research conducted in Nigeria, most of the physicochemical values found

Table 1. Mean summary of physicochemical parameters of Tayagi River Niger State.

Parameters	Sampling stations			P-value	
	Station 1	Station 2	Station 3	Stations	Months
Temperature (°C)	28.33±1.17	29.36±1.67	26.66±0.70	0.321	0.69
Depth (cm)	38.88±8.49	53.2 ±12.23	43.33±13.06	0.670	0.002
Flow velocity (m/s)	0.019±0.03	0.017±0.01	0.29±0.09	0.291	0.204
Transparency (cm)	30.73±7.47	39.03±7.23	37.46±8.38	0.795	2.20E-05
pH	7.02±0.13	7.06±0.17	7.08±0.09	0.954	0.05
Electrical conductivity(μS/cm)	69.16±8.03	75.66 ±10.24	77.66 ±10.76	0.814	2.80E-07
Total alkalinity (mg/L)	44.5±4.48	43.33±6.21	41.00 ±5.83	0.903	2.36E-07
Total hardness (mg/L)	53.33±4.80	52.50±6.94	49.83±5.98	0.939	1.57E-07
Dissolved oxygen (mg/L)	5.91±0.48	6.16±0.48	5.43±0.38	0.519	0.006
BOD_5 (mg/L)	3.05±0.32	2.73±0.19	2.86±0.27	0.679	0.27
Phosphate (mg/L)	0.18±0.01	0.11±0.01	0.08±0.01	0.303	0.009
Nitrate (mg/L)	0.71±0.10	0.69±0.07	0.70±0.10	0.985	2.28E-06

during this investigation were consistent with a normal tropical climate environment (Arazu & Ogbeibu, 2017; Mohammed et al., 2020; Mohammed et al., 2021; Edegbene et al., 2022; Garba et al., 2022; Maishanu et al., 2022; Mohammed et al., 2023). Most of the observed physicochemical parameters in this study were within the maximum acceptable limit for freshwater as recommended by world health organization. Since elevated DO and Low BOD_5 has been often used as a benchmark to measure generally unperturbed locations, the study's findings showed DO and BOD_5 content were moderate in all sample stations suggesting that the stations were less disturbed (Omovoh et al., 2022). Other studies from Nigeria and other part of the globe have reported the increase in agricultural activity along water catchments, and reported the degradation of rivers and streams water quality (Cornejo et al., 2020; Garba et al., 2022; Edegbene et al., 2023).

Structural assemblages of macroinvertebrates and their functional feeding group in Tayagi River Agaie Niger State.

In this study, we assessed the ecological integrity of Tayagi river, a rural river in North-central Nigeria using macroinvertebrate diversity and their functional feeding groups. A total 136 individuals of macroinvertebrates belonging to 10 species were recovered from the sampling stations of Tayagi River, Agaie Niger State (Table 2). Order Ephemeroptera was represented by two species which are *Telegan* sp. and *Baetis* sp. Arachnida was represented by *Dolomedes* sp. only. Order Odonata was represented by two species namely; *Ophiogomphus* sp. and *Libellula* sp. Order Hemiptera was also represented by two species which are *Nepa* sp. and *Gerris* sp. Order Coleoptera was highest in term of species assemblage with three species which are *Crenis* sp., *Octhebius* sp. and *Agasicles hygrophyla.*

The few individuals and diversity of macroinvertebrates recorded could be attributed to the impact of different human activities around the river. In the study conducted in the Bode River in Germany by Ronald et al. (2015), the lower abundance of macroinvertebrates recorded was attributed to the impact of anthropogenic activities such as farming, gold mining, washing, and bathing, which were recorded in their study, as these activities have been found to disrupt macroinvertebrate abundance as reported by Arimoro & Keke (2017), Keke et al., 2017; Edegbene et al. (2019) and Akinpelu et al. (2024). Also, Habitat destruction as a result of urban development, deforestation and agriculture practices can significantly reduce the population of macroinvertebrates in freshwater ecosystems which could lead to decline in biodiversity (Edegbene et al., 2019; Mohammed et al., 2021). Barriers along the course of the river could alter natural flow regimes, fragment habitats, and impede the movement of macroinvertebrates within freshwater ecosystems. These physical barriers can disrupt breeding and feeding behaviours, limiting the ability of macroinvertebrates to thrive and maintain diverse populations.

Table 2. Macroinvertebrates structural assemblages of Tayagi River Agaie Niger State.

Order	Family	Species	Stations			Function feeding groups
			1	2	3	
Ephemeroptera	Teleganonidae	*Telegan*	2	0	0	Scraper
	Baetidae	*Baetis* sp.	3	0	0	Collector-Gatherer
Arachnida	Pisauridae	*Dolomedes* sp.	13	8	8	Predator
Odonata	Gomphidae	*Ophiogomphus* sp.	13	5	3	Predator
	Libellubidae	*Libellula* sp.	5	1	3	Predator
Hemiptera	Nepidae	*Nepa* sp.	11	3	1	Predator
	Gerridae	*Gerris* sp.	1	11	0	Predator
Coleoptera	Hydrophilidae	*Crenis* sp.	5	3	6	Predator
	Hydraenidae	*Octhebius sp.*	3	3	6	Predator
	Chrysomelidae	*Agasicles hygrophyla*	5	3	11	Scraper
Total			**61**	**37**	**38**	

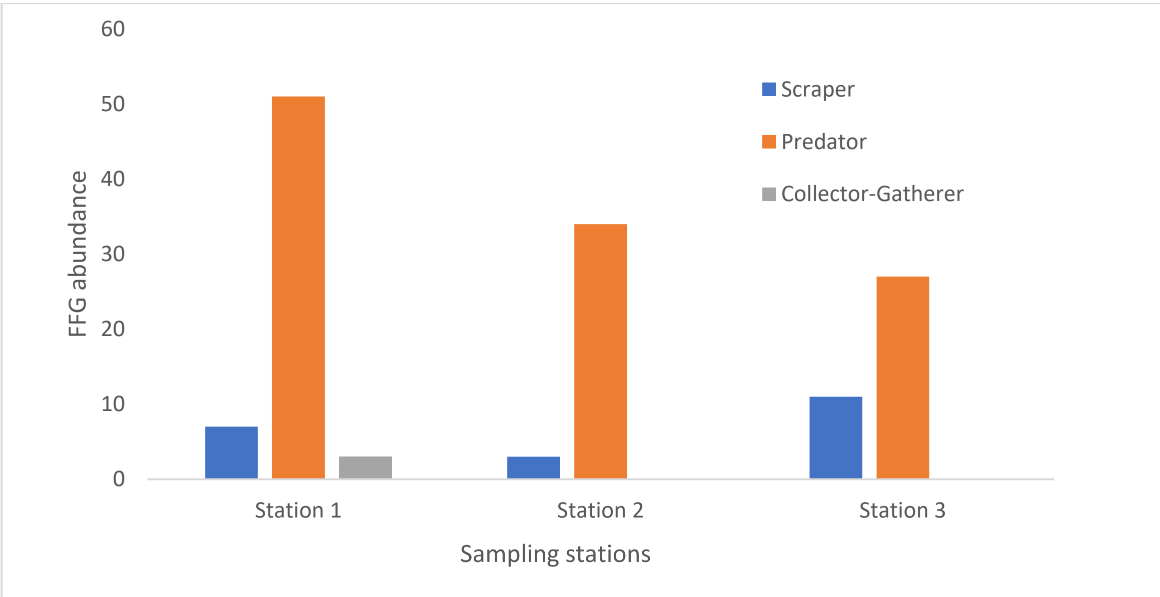

Fig. 2. Macroinvertebrates functional feeding group of Tayagi River Agaie Niger State

The low abundance of EPT species observed in this study could be as a result of habitat degradation as EPT species are sensitive to changes in water quality and habitat degradation, such as pollution, sedimentation, and habitat destruction (Akinpelu et al., 2024; Mohammed et al., 2024). These factors can directly impact the availability of suitable habitats and food resources for EPT species. Furthermore, the increasing agricultural activities around the river can also influence the distribution of EPT species as there are highly sensitive to water pollution particularly from agricultural runoff as pollutants such as pesticides and nutrients can directly harm EPT species, leading to reduced abundance (Arimoro & Keke 2016; Edegbene et al., 2023; Mohammed et al., 2024). Ikayaja et al., (2024) reported that agricultural activities such as organochlorine pesticide residue impact macroinvertebrates in River Chanchaga Niger State Nigeria. In freshwater Changes in water temperature, flow regimes, and precipitation patterns as a result of climate change can impact EPT populations. These species have specific temperature and flow requirements for development and survival, and alterations in these factors can negatively affect their abundance.

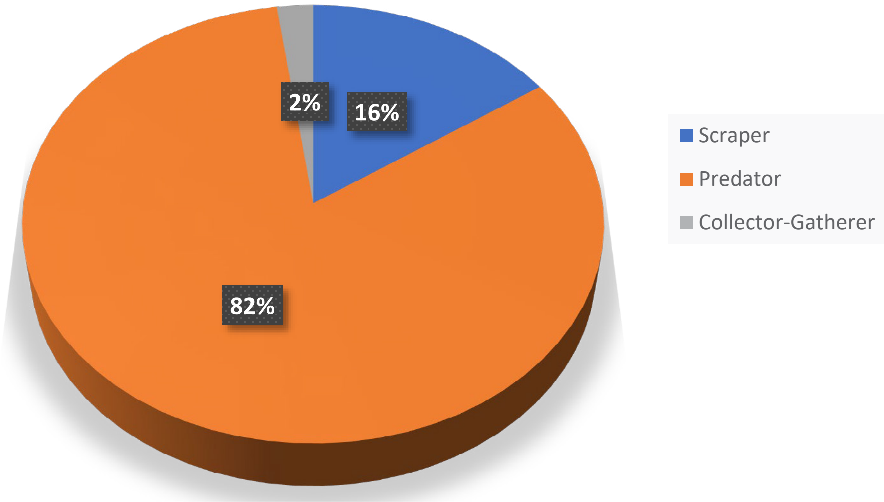

Fig. 3. Percentage abundance of macroinvertebrates functional feeding group of Tayagi River, Agaie, Niger State, Nigeria.

In this study, the Odonata were represented by the Gomphidae and Libellubidae families. The two families are predatory insects that inhabit freshwater habitats such as ponds, streams, and marshes (Edegbene et al., 2023). This groups of organisms have been reported to be sensitive to changes in water quality, habitat loss, and pollution, making them valuable bioindicators of ecosystem health (El Yaagoubi et al., 2024). Their presence and abundance have been reported in most freshwater bodies of Northern Nigeria as they have been reported to be moderately tolerance of pollution (Arimoro & Keke 2017; Keke et al., 2017; Mohammed et al., 2020; Mohammed et al., 2021; Adamu et al., 2022; Mohammed et al., 2024). Coleoptera and Hemiptera are one of the most diverse and abundant insect groups in freshwater ecosystems as they have been found in various habitats, including rivers, lakes, and wetlands. Many beetle and bug species are sensitive to pollution and changes in water quality, making them excellent indicators of environmental health. Hydrophilidae, Hydraenidae and Chrysomelidae are the beetle family recorded in this study. The presence of certain beetle species, such as water scavenger beetles (Hydrophilidae) is an indication of good water quality, while the absence of these species may indicate pollution or habitat degradation (El Yaagoubi et al., 2024). Hemipterans are sensitive to water quality and pollution, with some species being highly susceptible to contaminants like pesticides and heavy metals. In this study, the Hemipterians were represented by the Nepidae and Gerridae family, and this groups of organisms have been widely used as bioindicators of water quality. The presence and diversity of Coleoptera and the hemiptera in Tayagi river could be attributed to factors such as the habitat's complexity, availability of resources, sediment at the bottom, and vegetation cover that support their colonization and distribution in the aquatic ecosystem (Adedapo et al. 2023; Akinpelu et al., 2024). These group of organisms play important ecological roles by preying on other invertebrates and small vertebrates, helping to regulate prey populations. Additionally, beetles contribute to the decomposition of organic matter and act as detritivores in freshwater ecosystems (El Yaagoubi et al., 2024). They are commonly used in biomonitoring assessments of freshwater habitats due to their sensitivity to environmental disturbances (Mohammed et al. 2020; Mohammed et al. 2021; Adamu et al. 2022; Edegbene et al. 2023). Changes in the community composition and abundance of these organisms can serve as indicators of the health and condition of aquatic environments, making them valuable for monitoring water quality (Umar et al. 2013, Adamu et al. 2022; Edegbene et al. 2023 Akinpelu et al., 2024).

Table 3. Diversity indices of Macroinvertebrates from Tayagi River Agaie Niger State, Nigeria.

	Station 1	Station 2	Station 3
Taxa_S	10	8	7
Individuals	61	37	38
Dominance_D	0.149	0.180	0.191
Shannon_H	2.059	1.875	1.766
Evenness_e^H/S	0.783	0.814	0.835
Margalef	2.189	1.939	1.649

Macroinvertebrates with predatory feeding habit dominate all the sampled stations in this study as the numbers of collector-gatherers and scrapers were extremely low. This could be as a result of indiscriminate agricultural practice along the course of the river. 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 & Prommi 2015).

The lack of shredders in all the sampling station may be related to the loss of canopy cover. In general, the lack of shredders, low abundance of scrapers, and collector-gatherers could be attributed to the various anthropogenic activities leading to riparian vegetation loss or reduction (Dıaz et al., 2012; Addo-bediako *et al.,* 2021). Researchers have reported that macroinvertebrate diversity can be lost and their structural and functional organisation altered in streams when riparian vegetation is lost (Jinggut et al. 2012; Addo-Bediako, 2021; Akamagwuna et al., 2022). It has also been noted that in certain tropical and subtropical rivers, predators predominate in every sampling site (Mishra and Nautiyal 2013; Addo-Bediako, 2021). The presence of food and reduced competition may be the cause of the great taxonomic richness of predators in the sampled stations.

The dynamics of the food web are significantly shaped by the dominance of predator species. By controlling prey populations, these predators avoid overpopulation and maintain the stability of the environment. As an ambush hunter, Dolomedes sp. has a major top-down control over the behaviour and abundance of insects and small animals (Baba et al., 2019). Similar to this, Nepa and Gerris spp. aid in the cycling of nutrients through scavenging and predation, whereas *Ophiogomphus* and *Libellula* sp. preserve the equilibrium of insect populations. By promoting both predation and decomposition processes, the presence of *Crenis* sp. and *Octhebius* sp. strengthens the robustness of the food web. *Agasicles hygrophila* also shapes habitat conditions for primary consumers and prey species by managing aquatic vegetation, which has an indirect impact on the food chain (Ngo & Nguyen 2021). By creating a well-organized trophic ladder, these predators support biodiversity and preserve the health of ecosystems.

Biological Indices

The diversity indices of macroinvertebrates of Tayagi River Agaie Niger State Nigeria are shown in Table 3. In term of species richness, station 1 had the highest followed by station 2 and station 3. Individuals' abundance was highest in station 1, followed by station 3 and lowest in station 2. Station 3 had the highest species dominance, followed by station 2 while the least dominance was observed in station 1. Shannon index was highest in station 1, followed by Station 2 and station 3 record lowest. Station 3 had the highest evenness, followed by station 2 while the least evenness was observed in station 1. Margalef index was highest in station 1, followed by station 2 while the lowest Margalef index was observed in station 3.

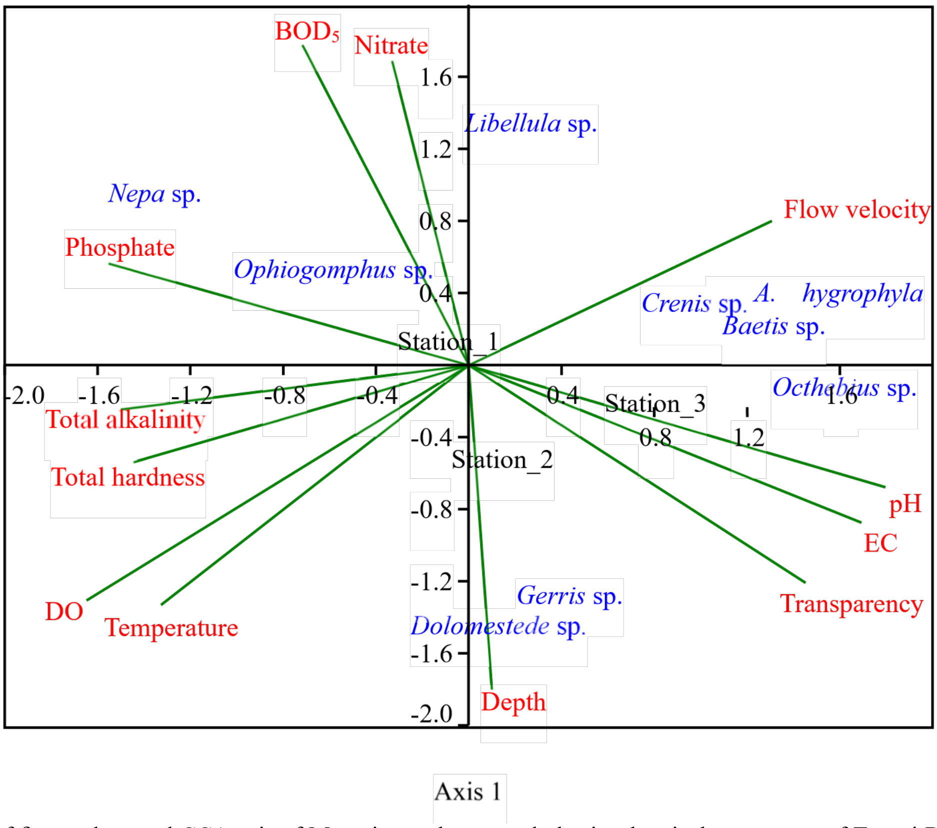

Fig. 4. Triplot of first and second CCA axis of Macroinvertebrates and physicochemical parameters of Tayagi River Agaie Niger State Nigeria

Because it represents disturbances in ecological processes and energy flow, the loss of Functional Feeding Group (FFG) variety is a powerful bioindicator of environmental disturbance. FFGs are essential to the stability of ecosystems and the cycling of nutrients because they classify animals according to their eating habits, such as shredders, grazers, predators, and filter feeders. Essential ecosystem processes deteriorate when stressors like pollution, habitat degradation, or climate change limit the diversity of these groups, indicating altered trophic relationships and decreased resilience. A loss of particular FFGs is a useful indicator for evaluating the sustainability and health of an ecosystem since it might reveal imbalances in food availability, slowed decomposition rates, or an overabundance of tolerant species (Carrasco-Badajoz et al., 2022).

Macroinvertebrate and the Environmental Relationships

The Canonical correspondence analysis (CCA) axis 1 accounted for 64.93% of the species variation while CCA axis 2 accounted for 35.07% of the species variation with eigen value of less than1 indicating weak or no relationship. The canonical correspondence analysis of the macroinvertebrate species and physicochemical data of the river shows little or no relationship as the eigen values recorded for both axis are less than1 (<1). The CCA axis 1 accounts for 64.93% of the species variation while CCA axis 2 account for 35.07% of the specie variation. Organisms in axis 1 were positively influenced by depth, flow rate, transparency, pH and electrical conductivity. The organisms in axis 2 were influenced by flow velocity, BOD_5, phosphate and nitrate as shown in Fig 4. In terms of functional feeding groups, only three FFGs were recorded in this group which are scrapers, predators and collector-gatherers. Figure 2 shows the FFG abundance of the sampling stations of the river. Scraper abundance was highest in station 3 and its lowest abundance was observed in station 2. Predator's abundance was highest in station 1 and lowest in station 3 Collector-gatherers were recorded in station 1 only. Percentage abundance of FFG shows that 82% of the macroinvertebrates collected from the river were predators, 16% were scrapers and 2% were collector-gatherers (Fig 3).

The direction and length of the vectors represent the strength and nature of relationships. For instance, species closer to a specific environmental variable are likely more influenced by it. *Libellula* sp. and *Baetis* sp. are positioned near variables such as BOD5 and Nitrate, suggesting their association with water quality indicators. *Gerris* sp. and *Dolomedes* sp. appear closer to Flow velocity, indicating a preference for faster-moving water. The distribution of species along different environmental variables shows how they respond to conditions such as pH, DO, temperature, and transparency. Species positioned along the axis of depth and total hardness may thrive in deeper, mineral-rich environments. From the vectors pointing in opposite directions suggest contrasting environmental effects. Temperature and DO have vectors pointing in different directions, which aligns with real world observations higher temperatures often reduce dissolved oxygen levels.

CONCLUSION

This study provides the current ecological condition of Tayagi River, Agaie, Niger State using physicochemical data, macroinvertebrates and their functional feeding groups. Our findings revealed that the overall health status of Tayagi river has been impaired with different anthropogenic activities such as washing of clothes, home utensils and agricultural activities as shown by the low abundance of pollution-sensitive macroinvertebrates of the orders Ephemeroptera and the absence of Plecoptera and Trichoptera group. Similarly, the absence of some functional feeding groups such as shredders, collector-filterers and other taxonomic groups during the sampling period is an indication of extensive anthropogenic activities along the bank of the river. As a result, it is possible to conclude that despite the anthropogenic activities around the river, it has minimal impact on the health status of Tayagi River. Sustainable management practices such as reduction of nutrient pollutant, sustainable land use and management practices, engagement of the community, regular monitoring, and conservation efforts are important to restore and protect our rivers. In addition, enforcing policies and measures to mitigate negative impacts, afforestation, and ecological restoration are recommended to conserve and protect the river's ecosystem.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not 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.

REFERENCES

Adamu, K. M. Mohammed, Y. M., Ibrahim, U. F., Abdullahi, I. L., & Jimoh, Y. O. (2022). Assessment of some physical, chemical and biological parameters of Lake Dangana, Niger State, Nigeria. *The Zoologist, 20,*133-140. http://dx.doi.org/10.4314/tzool.v20i1.17.

Addo-Bediako A. (2020). Assessment of heavy metal pollution in the blyde and steelpoort rivers of the olifants river system, South Africa. *Polish Journal of Environmental Studies,29*(5), 1–9.

Addo-Bediako, A. (2021) Spatial distribution patterns of benthic macroinvertebrate functional feeding groups in two rivers of the olifants river system, South Africa. *Journal of Freshwater Ecology, 36*(1), 97-109, DOI: 10.1080/02705060.2021.1901789.

Adedapo, A.M., Kowobari, E.D., Fagbohun, I.R., Oladeji, T.A., Amoo, T.O., Akindele, E.O., 2023. Using macroinvertebrate functional traits to reveal ecological conditions of two streams in Southwest Nigeria-a case study. *Aquatic Ecology.* https://doi.org/10.1007/s10452- 10010-4.

Akamagwuna F.C., Odume, O.N., & Richoux, N.B. (2022). Exploring the community structure of Afrotropical macroinvertebrate traits and ecological preferences along an agricultural pollution gradient in the Kat River, Eastern Cape, South Africa. *Ecological Indicators 135*,108570, https://doi.org/10.1016/j.ecolind.2022.108570.

Akindele, E.O. & Liadi, A.A. (2014). Diversity and response of benthic macrovertebratesto stress 101 and Response of Benthic Macroinvertebrates to Natural and Induced Environmental Stresses in Aiba Stream, Iwo, Southwestern Nigeria. *West African Journal of Applied Ecology, 22*(1), 101-111.

Akinpelu, O.T., Arimoro, F.O., Ayanwale, A.V., Chukwuemeka, V.I., Adedapo, A.M. & Akindele E.O. (2024). Comparative investigation provides further insights on how riparian deforestation and different land uses impact the distribution of freshwater macroinvertebrates in Nigerian streams. *Ecohydrology & Hydrobiology,* https://doi.org/10.1016/j.ecohyd.2024.01.006

APHA (American Public Health Association) (2012). Standard Methods for the Examination of Water and Wastewater. WEF and AWWA. 20th Edition; 2012: USA.

Arazu, V.N., & Ogbeibu, A.E. (2017). The composition, abundance and distribution of zooplankton of River Niger at Onitsha Stretch, Nigeria. *Animal Research International, 14*(1), 2629–2643.

Arimoro, F.O., & James, H.M. (2008). *Preliminary pictorial guide to the macroinvertebrates of Delta State Rivers, southern Nigeria*. Albany Museum, Grahamstown.

Arimoro, F.O., & Keke, U.N. (2017). The intensity of human-induced impact on the distribution and diversity of Macroinvertebrates and water quality of Gbako River, North Central Nigeria. *Energy Ecology & Environment,*16(8), 25-36. https://doi.org/10.1007/s40974-016-0025-8.

Baba, Y. G., Watari, Y., Nishi, M., & Sasaki, T. (2019). Notes on the feeding habits of the Okinawan fishing spider, Dolomedes orion (Araneae: Pisauridae), in the southwestern islands of Japan. *The Journal of Arachnology*, *47*(1), 154-158.

Carrasco-Badajoz, C., Rayme-Chalco, C., Arana-Maestre, J., Álvarez-Tolentino, D., Ayala-Sulca, Y., & Sanchez-Peña, M. (2022). Aquatic macroinvertebrate trophic guilds, functional feeding groups, and water quality of an andean urban river. *Frontiers in Environmental Science*, *10*, 1003207.

Cornejo, A., Perez, J., Lopez-Rojo, N., Tonin, A.M., Rovira, D., Checa, B., Jaramillo, N., Correa, K., Villarreal, A., Villarreal, V., García, G., P´erez, E., Ríos Gonz´ alez, T.A., Aguirre, Y., Correa-Araneda, F., & Boyero, L. (2020). Agriculture impairs stream ecosystem functioning in a tropical catchment. *Science of Total Environment, 745*, 140950. https://doi.org/10.1016/j.scitotenv.2020.140950.

Cummins, K. W. & Klug, J. M. (1979). Feeding ecology of stream invertebrates. *Annual Review of Ecology and Systematics*, *10*, 147-172.

Cummins, K.W., Merritt, R.W., & Andrade, P.C.N. (2005). The use of invertebrate functional groups to characterize ecosystem attributes in selected streams and rivers in south Brazil. *Studies on Neotropical Fauna and Environment, 40*, 69-89.

Day, J. A, Harrison, A.D., & de Moor I. J., (2002). *Guides to the freshwater invertebrates of Southern Africa, volume 9. Diptera* TT 201/02 Pretoria: Water Research Commission.

De Moor, I. J., Day, J.A. & De Moor, F. C. (2003). *Guides to the freshwater invertebrates of southern Africa.* Volume 8: In- secta II: Hemiptera, Megaloptera, Neuroptera, Trichoptera and Lepidoptera. Water Research Commision, 8. WRCReport No. TT 214/03.

Deemool M., & Prommi, T.O. (2015). Functional feeding groups of aquatic insects in the Mae Klong watershed for ecological assessment. *Advance Environmental Biology*, *9*(26):19–23

Dıaz, V., Albarino, R., & Canhoto, C. (2012). Positive effect of shredders on microbial biomass and decomposition in stream microcosms. *Freshwater Biology*, *57*(12), 2504–2513.

Dudgeon, D. (2019). Multiple threats imperil freshwater biodiversity in the Anthropocene. *Current Biology*, *29*(19), R960-R967.

Edegbene AO, Arimoro FO, Odoh O, Ogidiaka E (2015) Effect of anthropogenicity on the composition and diversity of aquatic insects of a municipal river in North Central Nigeria. Bioscience Res Today's World 1(1):55–66.

Edegbene, A.O., Arimoro, F.O., Odume, O.N. (2019). Developing and applying a macroinvertebrate-based multimetric index for urban rivers in the Niger Delta, Nigeria, Ecol. Evol. 9 (22) (2019) 12869–12885, https://doi.org/10.1002/ece3.5769.

Edegbene, A.O., Elakhame, L.A., Arimoro, F.O., Osimen, E.C., Akamagwuna, F.C., Edegbene Ovie, T.T., Akumabor, E.C., & Njuguna, C.W., (2023). Preliminary studies on macroinvertebrate biomonitoring of freshwater systems in the Afrotropics: a case study of the Chanchaga River in the Lower Niger-Benue Ecoregion of Nigeria. *Biologia,* DOI : 10.1007/s11756-023-01445-z.

Edegbene, A.O., Akamagwuna, F.C., Arimoro, F.O., Akumabor, E.C., Kaine, E.A. (2022). Effects of urban-agricultural land-use on Afrotropical macroinvertebrate functional feeding groups in selected rivers in the Niger Delta Region, Nigeria. *Hydrobiologia* https://doi.org/10.1007/s10750-022-05034-0.

El Yaagoubi S, Edegbene AO, El Haissoufi M, Harrak R, El Alami M (2024) Odonata, Coleoptera, and Heteroptera (OCH) Trait-Based Biomonitoring of Rivers within the Northwestern Rif of Morocco: Exploring the Responses of Traits to Prevailing Environmental Gradients. Ecologies, 5: 132–154. https:// doi.org/10.3390/ecologies5010009

Emere, M. C., & Nasiru, C. E. (2009). Macroinvertebrate as Indicator of the water quality of an Urbanized stream, Kaduna Nigeria. *Journal of aquatic sciences*, 7, 2-3.

Feio, M.J., Hughes, R.M., Serra, S.R., Nichols, S.J., Kefford, B.J., Lintermans, M., & Sharma, S. (2023). Fish and macroinvertebrate assemblages reveal extensive degradation of the world's rivers. *Global Change Biology*, *29* (2), 355–374

Garba, F., Ogidiaka, E., Akamagwuna, F.C., Nwaka, K.H., & Edegebene A.O. (2022). Deteriorating water quality state on the structural assemblage of aquatic insects in a North- Western Nigerian River. *Water Science, 36*(1), 22–31. https://doi.org/10.1080/23570008.2022.2034396.

Gerber, A., & Gabriel, M. J. M. (2002). *Aquatic invertebrates of South African Rivers field guide*. Institute of water quality studies South Africa.

Ghasemi, A.F., & Kamali, M. (2014). Benthic macroinvertebrates along the Haraz downstream in southern Caspian sea basin: in gradient of the physicochemical parameters. *International Journal of Zoology*, *2,* 1–7

Ikayaja, E.O., Babalola, G.A., Zabbey, N., Arimoro, F.O. (2024). Agricultural-Derived organochlorine pesticide residues impact on macroinvertebrate community in an Afrotropical Stream. *Heliyon, 10,* e34606. https://doi.org/10.1016/j.heliyon.2024.e34606

Jinggut, T., Yule, C.M., & Boyero, L. (2012). Stream ecosystem integrity is impaired by logging and shifting agriculture in a global megadiversity center (Sarawak, Borneo). *Science of the Total Environment, 437*, 83-90.

Jun, Y.C., Kim, N.Y., Kim, S.H., Park, Y.S., Kong, D.S., & Hwang, S.J. (2016). Spatial distribution of benthic macroinvertebrate assemblages in relation to environmental variables in Korean Nationwide streams. *Water*, *8*(1), 1-27.

Keke, U.N., Arimoro, F.O., Auta, Y.I., & Ayanwale, A.V. (2017). Temporal and spatial variability in macroinvertebrate community structure in relation to environmental variables in Gbako River, Niger State, Nigeria. *Tropical Ecology,* 58(2), 229-240.

Magbanua, F.S., Hilario, J.E., Salluta, J.C., Alpecho, B.C., Mendoza, S.S., & Lit, I.L. (2023). Freshwater biomonitoring with macroinvertebrates in the Philippines: Towards the development of the Philippine biotic index. *Limnologica*, *102,* 126098. https://doi.org/10.1016/j.limno.2023.126098.

Maishanu, F., Adamu K.M., & Mohammed, Y.M. (2022). Anthropogenic impact on some water quality characteristics of Wupa River Federal Capital Territory, Abuja, Nigeria. *Issues in Biological Science* and *Pharmaceutical Research, 10*(3), 30-38. https://doi.org/10.15739/ibspr.22.006

Merrit, R. W., Cummins, K. W., & Berg, M. B. (2008). An Introduction to the Aquatic Insects of North America, 4th ed. Kendall Hunt Publishing Company. Kendall Hunt Publishing Company, Dubuque

Merritt, R.W., & Cummins, K. W. (1996). An Introduction to the Aquatic Insects of North America, Kendall/Hunt, Dubuque:

Mishra, A.S., & Nautiyal, P. (2013). Functional composition of benthic macroinvertebrate fauna in the plateau rivers, Bundelkhand, central India. *Journal of Threat Taxa, 5*(13), 4752-4758.

Mohammed, Y.M., Adamu, K.M., Ibrahim, B.U., Danjuma, S., & Amuzat, A.O. (2023). Exploring the Impact of Human Activities on Water Quality Characteristics of a Rural River in North-Central Nigeria using Macroinvertebrates Structural Assemblage. *West African Journal of Life Sciences,* 1(1), 023-034.

Mohammed, Y.M., Arimoro, F. O., Ayanwale, A.V., Adama, B. S., Keke, U.N., Auta, Y. I. & Umar, B.L. (2020). Seasonal changes in the abundance of benthic macroinvertebrates & physico-chemical condition of Moussa stream Bida, Nigeria. *Tropical Freshwater Biology,* 29(1), 57-70. DOI: https://dx.doi.org/10.4314/tfb.v29i1.4.

Mohammed, Y.M., Arimoro, F.O., Ayanwale, A.V. Adamu, K.M., Keke, U.N., Abubakar, M.D. & Achebe, A.C. (2021). The current state of water quality and benthic invertebrate fauna in Chikke Stream (North-Central Nigeria). *Ukranian Journal of Ecology*, 11(3),26-34. DOI: 10.15421/2021_136

Namba, H., Iwasaki, Y,. Heino, J., & Matsuda, H. (2020). What to Survey? A Systematic review of the choice of biological groups in assessing ecological impacts of metals in running waters. *Environment Toxicology Chemistry, 39*(10), 1964-1972. DOI: 10.1002/etc.4810.

Ngo, Q. P., & Nguyen, M. T. (2021). The genus Ophiogomphus Lieftinck, 1964 in Vietnam, with descriptions of the female of O. minimus Karube, 2014 and O. phantoani sp. nov.(Odonata: Gomphidae). *Zootaxa*, *5061*(1), 134-144.

Omovoh, B.O., Arimoro, F.O., Anyanwale, A.V., Egwim, E.C., Omovoh, G.O., Akamagwuna, F.C., Zakari, H., & Edegbene, A.O. (2022). Macroinvertebrates of Wupa River, Abuja, Nigeria: Do environmental variables pattern their assemblages?. *Biology Insights,* 1, 612 https://doi.org/10.55085/bi.2022.612

Ramírez, A., & Gutiérrez-Fonseca, P.E. (2014). Functional feeding groups of aquatic insect families in Latin America: a critical analysis and review of existing literature. Review of Biology Tropical. *International Journal of Tropical Biology,* 62 (2), 155-167.

Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T., ... & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*(3), 849-873. https://doi.org/10.1111/brv.12480.

Ronald, M., Polina, O., Roman, G., Albrecht, P., Oliver, K., Mikhail, A.B. Matthias, H. & Coretta, B. (2015). Pesticide impact on aquatic invertebrates identified with Chemcatcher passive samplers and the SPEAR pesticides index, Sci. Total Environ. 537 (2015) 69–80, https://doi.org/10.1016/j.scitotenv.2015.07.012.

Umar, D.M., Hardling, J.S., & Winterbourn, M.J. (2013). *Photographic guide of freshwater Invertetbrates of the Mambilla Plateau Nigeria*. Published by School of Biological Sciences University of Canterbury, New Zealand.