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# Influence of Physico-Chemical Variables on the Functional Locomotion Structure of Macroinvertebrate Communities in Owena River, Southwestern Nigeria

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## ABSTRACT

**This study evaluated the influence of physico-chemical variables on the locomotion-based functional structure of macroinvertebrate communities in Owena River, Southwestern Nigeria. Sampling was conducted at six stations during the dry (November and January, 2024) and wet seasons (May and June, 2025) and water quality variables were analysed together with macroinvertebrate assemblages. Most physico-chemical parameters showed no significant spatial variation, whereas DO, T, TDS, EC, BOD, $PO_4^{3-}$, $Mg^{2+}$, $Ca^{2+}$, and hardness differed significantly between seasons. A total of 1,243 macroinvertebrate individuals representing 58 genera were recorded, with Odonata and Hemiptera constituting the dominant taxa, while pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera were poorly represented. Functional classification identified climbers as the predominant locomotion group, followed by crawlers and clingers, indicating the ecological importance of submerged vegetation and stable benthic substrates. Canonical Correspondence Analysis (CCA) demonstrated that DO, EC, TDS, $PO_4^{3-}$, $Mg^{2+}$, and hardness were the principal environmental variables associated with variations in functional community structure. The predominance of vegetation-associated taxa, coupled with the reduced occurrence of sensitive taxa, suggests that Owena River retains substantial habitat heterogeneity but is subject to moderate anthropogenic disturbance. The findings demonstrate that combining physico-chemical assessment with taxonomic and locomotion-based functional analyses provides a sensitive and comprehensive framework for evaluating ecological condition and environmental change in tropical river ecosystems.**

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## 1.0 INTRODUCTION

Freshwater ecosystems are among the most valuable natural resources on earth because they provide drinking water, irrigation, fisheries, hydroelectric power and habitat for a wide range of aquatic organisms (Kumar *et al.,* 2022). Rivers constitute an important component of these ecosystems and play an important role in maintaining biodiversity and ecological processes. However, freshwater habitats are increasingly threatened by anthropogenic activities such as urbanization, agricultural runoff, domestic waste disposal and industrial discharges, all of which contribute to the deterioration of water quality and alteration of aquatic communities (Mateo-Sagasta *et al*., 2017; Bashir *et al.,* 2020). The resulting changes in environmental conditions can disrupt ecosystem functioning, reduce biodiversity, and impair the ecological integrity of riverine systems (Sharma *et al.,* 2020).

Aquatic macroinvertebrates are integral components of freshwater ecosystems and are widely recognized as effective biological indicators of environmental quality (Gholizadeh & Heydarzadeh, 2019). This diverse group includes aquatic insects, mollusks, crustaceans, annelids, and other invertebrates that inhabit bottom substrates, vegetation, and sediments of water bodies (Hussain & Pandit, 2012). Macroinvertebrates contribute to energy transfer, nutrient cycling, organic matter decomposition, and trophic interactions within aquatic food webs (Karim *et al*., 2021). Their relatively long life cycles, limited mobility, ease of sampling and broad range of tolerance to environmental stressors make them particularly useful for assessing both present and past ecological conditions of freshwater systems (Bagalwa *et al.,* 2019). The structure of macroinvertebrate communities is strongly influenced by physicochemical characteristics of the water. Parameters such as temperature, dissolved oxygen, pH, electrical conductivity, total dissolved solids, nutrients, and biochemical oxygen demand affect the distribution, abundance, growth, and survival of aquatic organisms (Zhang *et al*., 2021). Variations in these environmental variables can lead to shifts in species composition and functional organization of macroinvertebrate assemblages. Consequently, integrating biological indicators with physicochemical assessments provides a more reliable evaluation of river health than the use of chemical measurements alone (Mohan & Latha, 2013).

Owena River is one of the major freshwater systems in Southwestern Nigeria and serves as an important source of potable water, fisheries resources, irrigation, and other domestic uses for surrounding communities (Oyhakilome *et al.,* 2012). The river is subjected to multiple anthropogenic pressures including agricultural activities, washing of farm tools, fishing operations, open defecation, and direct disposal of domestic wastes (Olaniyan & Akinkuolie, 2016). These activities have the potential to introduce nutrients, organic matter, and other pollutants into the river, thereby affecting water quality and aquatic biodiversity. Despite the ecological and socio-economic importance of Owena River, available information on the functional organization of its macroinvertebrate community remains limited. Previous investigations on Nigerian rivers have demonstrated that elevated nutrient concentrations, increased conductivity, higher total dissolved solids, and reduced dissolved oxygen can alter macroinvertebrate assemblages and favor pollution-tolerant taxa. Studies on rivers such as Aiba Stream, Opa River, Ona River, and Oluwa River have reported that anthropogenic disturbances influence macroinvertebrate diversity, abundance, and community composition (Akindele *et al*., 2014; Amusan *et al*., 2018; Olaniyan *et al.,* 2019). However, these studies largely emphasized taxonomic and feeding-group responses, with little attention given to locomotion-based functional structure and microhabitat preference.

The relationship between physicochemical variables and locomotion-based functional groups has received considerable attention in temperate freshwater ecosystems, but information from tropical African rivers remains limited. Most studies in Nigeria have focused on taxonomic composition, diversity indices, or functional feeding groups of macroinvertebrates (Amusan *et al.,* 2018; Olaniyan *et al*., 2019). Although these approaches have improved understanding of river health, they provide less information about habitat-related functional responses. Locomotion and microhabitat preference offer an additional ecological dimension that can reveal how environmental conditions influence habitat utilization and behavioral adaptations of aquatic organisms. This study therefore examined the influence of physicochemical variables on the functional locomotion structure of macroinvertebrate communities in Owena River, Southwestern Nigeria.

## 2.0 MATERIALS AND METHODS

### 2.1 Study area

The study was carried out on Owena River located within Idanre/Owena Local Government Area of Ondo State, Southwestern Nigeria. The area lies between latitude 7°17′ and 8°15′ N and longitude 5°01′ and 5°45′ E, with an elevation of approximately 249 m above sea level. Idanre is situated about 21.6 km from Akure, the Ondo State capital, and 23 km from Ondo town. The region is located within the tropical rainforest ecological zone and experiences two distinct seasons, namely the wet and dry seasons. The vegetation is predominantly composed of evergreen woody trees with heights ranging from 20 to 40 m, and the trees are characterized by relatively small leaves. The wet season extends from May to October, lasting for about seven months, with an average annual rainfall of approximately 100 ± 40 cm and a mean temperature of about 28°C. Rainfall is usually most intense between July and October, whereas the dry season occurs from November to April.

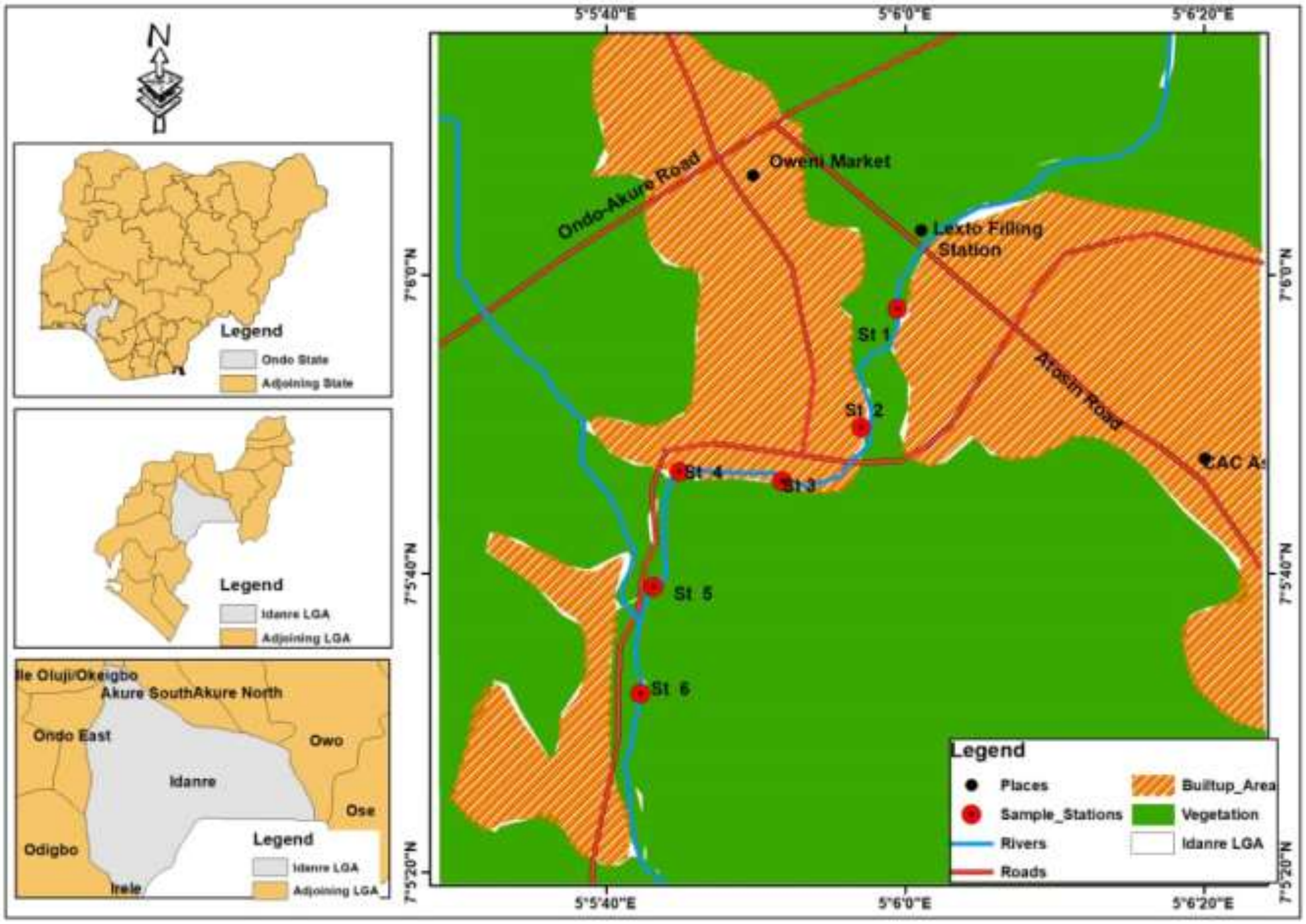


**Figure 1: Map of the study area showing the location of the six sampling stations (St1-St6) on Owena River, Southwestern Nigeria.**

## 2.2 Sampling design

Six sampling stations (St1–St6) were selected along the river to represent different habitat conditions and varying levels of anthropogenic influence. Sampling was carried out on four occasions, comprising two sampling periods during the dry (November and January, 2024) season and two during the wet season (May and July, 2025) in order to evaluate spatial and seasonal variations in water quality and macroinvertebrate communities.

## 2.3 Collection and analysis of water samples for physicocohemical analysis

For the assessment of water quality, six sampling stations were established along Owena River. Water samples were collected on four sampling occasions, comprising two collections during the dry season and two collections during the wet season. To minimize the influence of diurnal fluctuations, all sampling activities were conducted between 8:00 a.m. and 11:00 a.m. at each station. Water samples were collected using 1 L sterilized plastic bottles, which were submerged with the mouth facing upstream against the direction of water flow in accordance with standard sampling procedures (APHA, 2017). Each sample was appropriately labeled with the sampling station and date of collection. Field measurements were carried out for water temperature, depth, and transparency. Physicochemical parameters including electrical conductivity (EC), pH, dissolved oxygen (DO), and total dissolved solids (TDS) were measured in situ using a Multi 3630 IDS digital meter. Laboratory analyses were subsequently performed for nitrate, phosphate, sulphate, alkalinity, magnesium, calcium, and water hardness following standard analytical procedures. For the determination of biochemical oxygen demand (BOD), water samples were collected in 250 mL amber bottles to prevent light penetration. The samples were incubated in the dark for five days, after which BOD was calculated as the difference between the initial dissolved oxygen concentration and the final dissolved oxygen concentration.

### 2.4 Collection and identification of macroinvertebrates

Aquatic macroinvertebrates were collected using a long-handled D-frame net and by hand picking from submerged vegetation, stones, woody debris, and bottom substrates. Sampling was conducted along the river margins and other accessible habitats within each station to ensure adequate representation of available microhabitats. Collected specimens were transferred into labeled sample containers and preserved in 70% ethanol. In the laboratory, macroinvertebrates were sorted, counted, and identified to the lowest practicable taxonomic level (mainly genus level) using standard taxonomic keys and identification guides for freshwater macroinvertebrates (De Moor *et al*. (2003), Umar (2013) and Suhling *et al*.(2014). Identified macroinvertebrates were classified into functional locomotion/microhabitat preference groups following established freshwater ecological classifications (Cummins, 2016)

## 3.0 Data analysis

Spatial and seasonal variations in physicochemical parameters and the macroinvertebrate were analyzed using one-way Analysis of Variance (ANOVA). Taxa diversity was evaluated using the Simpson, Shannon-Weiner, and Margalef indices, while the community structure was analyzed through the mode of locomotion/microhabitat preference. Canonical correspondence analysis (CCA) was used to establish the relationships between physicochemical parameters and macroinvertebrate abundance and the significance of the CCA ordination was tested using a Monte Carlo permutation test. Statistical analyses were conducted using Microsoft Excel, SPSS (Version 20) R and PAST(version 4.03).

## 4.0 RESULTS

### 4.1 Physico-chemical characteristics of Owena River

The spatial variation in the physicochemical parameters of Owena River is presented in Table 1. Except for sulphate and alkalinity, the physicochemical parameters did not show significant variations among the sampling stations ($p > 0.05$). The highest dissolved oxygen value ($7.02 \pm 0.53$ mg $L^{-1}$) was recorded in Station 1, whereas the lowest value ($6.45 \pm 1.05$ mg $L^{-1}$) was recorded in Station 4. Temperature ranged from $28.20 \pm 4.30$°C in Station 1 to $28.83 \pm 3.60$°C in Station 4. The maximum pH value ($8.19 \pm 0.46$) was observed in Station 1, while the minimum value ($7.93 \pm 0.23$) occurred in Station 5. Total dissolved solids ranged from $85.00 \pm 5.60$ mg $L^{-1}$ in Station 1 to $86.75 \pm 5.74$ mg $L^{-1}$ in Station 3. Biochemical oxygen demand varied between $1.61 \pm 1.98$ mg $L^{-1}$ in Station 6 and $2.85 \pm 0.40$ mg $L^{-1}$ in Station 3. Electrical conductivity ranged from $127.30 \pm 7.88$ µS $cm^{-1}$ in Station 1 to $129.65 \pm 4.86$ µS $cm^{-1}$ in Station 3. Phosphate concentration was relatively consistent across the stations, ranging from $0.08 \pm 0.01$ to $0.08 \pm 0.02$ mg $L^{-1}$. Magnesium concentration ranged from $3.79 \pm 0.28$ mg $L^{-1}$ in Station 3 to $4.75 \pm 1.24$ mg $L^{-1}$ in Station 1. Calcium concentration ranged from $7.74 \pm 0.55$ mg $L^{-1}$ in Station 6 to $8.75 \pm 0.28$ mg $L^{-1}$ in Station 3. Sulphate showed significant spatial variation ($p < 0.001$), with the lowest value ($4.58 \pm 0.01$ mg $L^{-1}$) recorded in Station 4 and the highest value ($5.52 \pm 0.01$ mg $L^{-1}$) in Station 5. Nitrate concentration ranged from $2.82 \pm 1.23$ mg $L^{-1}$ in Station 4 to $7.90 \pm 5.55$ mg $L^{-1}$ in Station 5. Alkalinity also differed significantly among stations ($p < 0.01$), ranging from $236.00 \pm 25.56$ mg $L^{-1}$ in Station 3 to $287.00 \pm 7.39$ mg $L^{-1}$ in Station 4. Water hardness ranged from $36.95 \pm 5.37$ mg $L^{-1}$ in Station 2 to $40.47 \pm 2.56$ mg $L^{-1}$ in Station 4.

**Table 1. Spatial variation in the physicochemical parameters of Owena River, Southwestern Nigeria**

| Parameter | St1 | St2 | St3 | St4 | St5 | St6 | F | P |
|---|---|---|---|---|---|---|---|---|
| DO (mg/L) | 7.02±0.53 | 6.79±0.34 | 6.88±0.47 | 6.45±1.05 | 6.52±1.30 | 6.71±0.36 | 0.316 | 0.896 |
| pH | 8.19±0.46 | 8.10±0.37 | 8.06±0.31 | 8.01±0.20 | 7.93±0.23 | 8.01±0.26 | 0.309 | 0.900 |
| TDS (mg/L) | 85.00±5.60 | 85.50±5.60 | 86.75±5.74 | 86.00±3.30 | 85.75±6.02 | 85.75±6.02 | 0.043 | 0.998 |
| Temperature (°C) | 28.20±4.30 | 28.53±4.69 | 28.32±5.48 | 28.83±3.60 | 28.28±3.99 | 28.30±4.43 | 0.010 | 0.999 |
| BOD (mg/L) | 1.85±2.44 | 1.99±2.18 | 2.85±0.40 | 2.50±0.68 | 2.05±0.45 | 1.61±1.98 | 0.013 | 0.999 |
| EC (µS/cm) | 127.30±7.88 | 127.83±8.67 | 129.65±4.86 | 128.03±8.56 | 128.98±9.50 | 128.93±8.71 | 0.044 | 0.998 |
| $PO_4^{3-}$ (mg/L) | 0.08±0.02 | 0.08±0.02 | 0.08±0.02 | 0.08±0.01 | 0.08±0.01 | 0.08±0.01 | 0.027 | 0.999 |
| $Mg^{2+}$ (mg/L) | 4.75±1.24 | 4.10±0.76 | 3.79±0.28 | 4.74±0.54 | 4.55±0.88 | 4.54±0.34 | 1.056 | 0.416 |
| $Ca^{2+}$ (mg/L) | 8.03±0.55 | 8.05±0.90 | 8.75±0.28 | 8.41±0.15 | 7.93±0.51 | 7.74±0.55 | 1.798 | 0.164 |
| $SO_4^{2-}$ (mg/L) | 5.16±0.01 | 5.16±0.01 | 4.89±0.52 | 4.58±0.01 | 5.52±0.01 | 5.51±0.01 | 11.810 | 0.000*** |
| $NO_3^-$ (mg/L) | 5.73±3.65 | 6.98±4.89 | 4.90±3.03 | 2.82±1.23 | 7.90±5.55 | 6.92±5.50 | 0.735 | 0.606 |
| Alkalinity (mg/L) | 271±14.17 | 266.25±11.56 | 236±25.56 | 287±7.39 | 238.25±22.04 | 246±20.26 | 5.185 | 0.004** |
| Water hardness (mg/L) | 39.53±6.46 | 36.95±5.37 | 37.39±1.71 | 40.47±2.56 | 38.48±4.83 | 37.94±2.52 | 0.388 | 0.850 |

The seasonal variation in the physicochemical parameters of Owena River is presented in Table 2. Paired t-tests revealed significant seasonal differences in dissolved oxygen, TDS, temperature, BOD, EC, phosphate, magnesium, calcium and water hardness, whereas pH, sulphate, nitrate and alkalinity did not differ significantly between seasons. Dissolved oxygen was higher in the wet season (7.20 ± 0.22 mg $L^{-1}$) than in the dry season (6.25 ± 0.30 mg $L^{-1}$). Total dissolved solids increased from 81.42 ± 3.20 mg $L^{-1}$ in the dry season to 90.17 ± 0.00 mg $L^{-1}$ in the wet season. Temperature was higher in the dry season (29.42 ± 6.30°C) than in the wet season (27.40 ± 3.63°C). Biochemical oxygen demand was substantially higher in the dry season (3.07 ± 3.20 mg $L^{-1}$) than in the wet season (0.64 ± 0.17 mg $L^{-1}$). Electrical conductivity increased from 121.83 ± 4.50 µS $cm^{-1}$ in the dry season to 134.74 ± 0.01 µS $cm^{-1}$ in the wet season. Phosphate concentration increased from 0.07 ± 0.01 mg $L^{-1}$ in the dry season to 0.09 ± 0.01 mg $L^{-1}$ in the wet season. Magnesium and calcium were also higher in the wet season (4.96 ± 0.64 and 8.57 ± 0.30 mg $L^{-1}$, respectively) than in the dry season (3.86 ± 0.40 and 7.73 ± 0.53 mg $L^{-1}$, respectively). Sulphate was slightly higher in the dry season (5.21 ± 0.40 mg $L^{-1}$) than in the wet season (5.05 ± 0.50 mg $L^{-1}$). Nitrate increased from 4.20 ± 0.80 mg $L^{-1}$ in the dry season to 7.55 ± 4.40 mg $L^{-1}$ in the wet season, while alkalinity decreased from 263.50 ± 22.00 mg $L^{-1}$ in the dry season to 251.33 ± 21.40 mg $L^{-1}$ in the wet season. Water hardness was significantly higher in the wet season (41.75 ± 2.30 mg $L^{-1}$) than in the dry season (35.17 ± 2.08 mg $L^{-1}$).

**Table 2: Seasonal variation in the physico-chemical parameters of Owena River, Southwestern Nigeria**

| Parameters | Mean±SD | | T-Test | |
|---|---|---|---|---|
| | **DRY** | **WET** | **T** | **P** |
| DO (mg/l) | 6.25±0.30 | 7.2±0.22 | -3.389 | 0.0195* |
| pH | 8.07±0.10 | 8.04±0.50 | 0.713 | 0.5077 |
| TDS (mg/l) | 81.42±3.20 | 90.17±0.00 | -13.105 | 4.6182*** |
| Temperature (° C) | 29.42±6.30 | 27.4±3.63 | 11.412 | 9.0460*** |
| BOD (mg/l) | 3.07±3.20 | 0.64±0.17 | 17.757 | 1.0390*** |
| EC (µS/cm) | 121.83±4.50 | 134.74±0.01 | -12.982 | 4.8340*** |
| Phosphate (mg/l) | 0.07±0.01 | 0.09±0.01 | -4.382 | 0.0071** |
| Magnesium (mg/l) | 3.86±0.40 | 4.96±0.64 | -3.766 | 0.0131* |
| Calcium (mg/l) | 7.73±0.53 | 8.57±0.30 | -4.550 | 0.0061** |
| Sulphate (mg/l) | 5.21±0.40 | 5.05±0.50 | 1.114 | 0.3158 |
| Nitrate (mg/l) | 4.2±0.80 | 7.55±4.40 | -2.165 | 0.0827 |
| Alkalinity (mg/l) | 263.5±22.00 | 251.33±21.40 | 2.291 | 0.0706 |
| Water Hardness (mg/l) | 35.17±2.08 | 41.75±2.30 | -4.629 | 0.0057** |

*Indicates significant difference ($p < 0.05$), **Indicates significant difference ($p < 0.01$)
***Indicates significant difference ($p < 0.001$)

**4.2 Taxonomic Composition and Abundance of macroinvertebrate in Owena River**

A total of 1,243 macroinvertebrate individuals belonging to 2 phyla, 4 classes, 10 orders, 27 families, and 58 genera were recorded during the study period (Table 3). Arthropoda constituted the dominant phylum, while Mollusca was represented by a smaller proportion of the collection. Among the orders, Odonata recorded the highest abundance, followed by Hemiptera, whereas Ephemeroptera and Coleoptera were comparatively less abundant. The family Libellulidae was the most diverse family within Odonata, while Coenagrionidae was also well represented. In Hemiptera, Gerridae, Nepidae, Belostomatidae, Notonectidae, Corixidae, and Veliidae were among the dominant families. The most abundant species was Pseudagrion hamoni, which accounted for 19.30% of the total macroinvertebrate collection. Other relatively abundant taxa included Brachythemis leucosticta, Ceriagrion glabrum, Anax imperator, and Diplonychus rusticus. The occurrence of pollution-sensitive taxa was relatively low and members of Ephemeroptera were represented by few individuals. Plecoptera were not recorded, while Trichoptera were absent from the collection.

**Table 3: Abundance of macroinvertebrates in Owena River, Southwestern Nigeria**

| Order | Families | Genus/species | Total Abundance | % Composition |
|---|---|---|---|---|
| Araneae | Pisauridae | *Dolomedes* sp. | 15 | 1.20 |
| | | *Thalassius* sp. | 22 | 1.77 |
| Araneae | Tetragnathidae | *Tetragnatha* sp. | 5 | 0.40 |
| Architaenioglossa | Ampullaridae | *Lanistes varicus* | 8 | 0.64 |
| Coleoptera | Gyrinidae | *Orectogyrus* sp. | 138 | 11.10 |
| | | *Orectogyrus* sp. B. | 11 | 0.88 |
| Decapoda | Potamonautidae | *Sudanonautes aubryi* | 2 | 0.16 |
| Ephemeroptera | Heptageniidae | *Afronurus* sp. | 3 | 0.24 |
| | | *Notonurus* sp. | 5 | 0.40 |
| Ephemeroptera | Leptophlebiidae | *Adenophlebiodes* sp | 3 | 0.24 |
| Ephemeroptera | Oligoneuriidae | *Elassoneuria candida* | 3 | 0.24 |
| Ephemeroptera | Tricorythidae | *Tricorythus* sp. | 1 | 0.08 |
| Hemiptera | Belostomatidae | *Sphaerodema* sp. | 49 | 3.94 |
| | | *Limnogeton* sp. | 2 | 0.16 |
| Hemiptera | Gerridae | *Eurymetra* sp. | 1 | 0.08 |
| | | *Limnogonus* sp. | 4 | 0.32 |
| Hemiptera | Hebridae | *Hebrus* sp. | 1 | 0.08 |
| Hemiptera | Hydrometridae | *Hydrometra* sp. | 8 | 0.64 |
| Hemiptera | Naucoridae | *Laccocoris* sp. | 14 | 1.12 |
| | | *Neomacrocoris* sp. | 6 | 0.48 |
| Hemiptera | Nepidae | *Laccotrephes* sp. | 1 | 0.08 |
| | | *Ranatra* sp. | 26 | 2.09 |
| Hemiptera | Notonectidae | *Erithares* sp. | 5 | 0.40 |
| Hemiptera | Veliidae | *Rhagovelia* sp. | 9 | 0.72 |
| Odonata | Calopterygidae | *Phaon iridipennis* | 10 | 0.80 |
| Odonata | Chlorocyphidae | *Chlorocypha curta* | 8 | 0.64 |
| | | *Chlorocypha pyriformosa* | 27 | 2.17 |
| Odonata | Coenagrionidae | *Agriocnemis maclachlani* | 11 | 0.88 |
| | | *Agriocnemis* sp. B | 3 | 0.24 |
| | | *Ceriagrion* sp. | 4 | 0.32 |
| | | *Elattoneura* sp. | 4 | 0.32 |
| | | *Pseudagrion glaucum* | 47 | 3.78 |
| | | *Pseudagrion hamoni* | 240 | 19.30 |
| | | *Pseudagrion melanicterum* | 63 | 5.06 |
| Odonata | Gomphidae | *Lestinogomphus* sp. | 1 | 0.08 |
| | | *Paragomphus* sp. | 1 | 0.08 |
| | | *Phyllomacromia* sp. | 3 | 0.24 |

| Order | Families | Genus/species | Total Abundance | % Composition |
|---|---|---|---|---|
| Odonata | Libellulidae | *Brachythemis leucosticte* | 21 | 1.68 |
| | | *Crocothemis erythrae* | 5 | 0.40 |
| | | *Neodythemis* sp. | 1 | 0.08 |
| | | *Olpogastra lugubris* | 14 | 1.12 |
| | | *Orthetrum chrysostigma* | 16 | 1.28 |
| | | *Orthetrum Julia* | 1 | 0.08 |
| | | *Palpopleura lucia* | 1 | 0.08 |
| | | *Palpopleura Portia* | 1 | 0.08 |
| | | *Trithemis annulata* | 6 | 0.48 |
| | | *Trithemis arteriosa* | 49 | 3.94 |
| | | *Urothemis assignata* | 13 | 1.04 |
| | | *Zygonoides* sp. | 5 | 0.40 |
| | | *Zygonyx natalensis* | 4 | 0.32 |
| Odonata | Macromiidae | *Atoconeura* sp. | 1 | 0.08 |
| Odonata | Platycnemididae | *Mesocnemis singularis* | 71 | 5.71 |
| Plecoptera | Perlidae | *Neoperla* spio | 20 | 1.60 |
| Lymnaeida | Planorbidae | *Biomphalaria* sp. | 1 | 0.08 |
| | | *Bulinus* sp. | 8 | 0.64 |
| | | *Helisoma* sp. | 15 | 1.20 |
| | | *Lymnaea* sp | 6 | 0.48 |
| Sorbeoconcha | Thiaridae | *Melanoides tuberculata* | 220 | 17.69 |
| **Total Percentage** | | | **1243** | **100** |

**4.3 Composition of locomotion and microhabitat preference groups**

The recorded macroinvertebrates were classified into five locomotion and microhabitat preference groups, namely climbers, crawlers, clingers, swimmers, and burrowers. The distribution and relative abundance of these groups are presented in Table 4. Climbers constituted the dominant locomotion group, followed by crawlers and clingers, whereas swimmers and burrowers were less represented. Climbers recorded the highest abundance with 478 individuals (38.46%), indicating the importance of submerged macrophytes, emergent vegetation, and accumulated plant debris as major microhabitats in Owena River. Crawlers constituted 327 individuals (26.31%) and were commonly associated with bottom substrates, leaf litter, and other stable surfaces. Clingers accounted for 251 individuals (20.19%) and were mainly represented by taxa adapted to attach firmly to coarse substrates and vegetation in flowing water. Swimmers were represented by 121 individuals (9.73%) and were associated with the water column and surface habitats, while burrowers recorded the lowest abundance with 66 individuals (5.31%), occurring mainly in stations characterized by fine sediments and organic deposits. The dominance of climbers and crawlers, together with the relatively low abundance of burrowers, suggested that vegetation-associated and surface substrates were more important habitats than soft sediments in the river.

**Table 4. Composition and relative abundance of locomotion and microhabitat preference groups in Owena River**

| Locomotion group | Description | Abundance | % |
|---|---|---|---|
| Climbers | Associated with submerged and emergent vegetation | 478 | 38.46 |
| Crawlers | Move actively on bottom substrates and leaf litter | 327 | 26.31 |
| Clingers | Attach firmly to coarse substrates and vegetation | 251 | 20.19 |
| Swimmers | Adapted for movement in the water column | 121 | 9.73 |
| Burrowers | Inhabit fine sediments and organic deposits | 66 | 5.31 |
| Total | | 1,243 | 100.00 |

The spatial distribution of macroinvertebrates based on their mode of locomotion and microhabitat preferences is as presented in Figure 2. Climbers emerged as the most abundant species while swimmers was the least abundant. Station 2 recorded the highest number of clingers while the least count was in Station 4. Crawlers were the most abundant at Station 1 while Station 4 accounted for the fewest number. The highest abundance of climbers was recorded in Station 2 while Station 5 had the lowest count. Skaters were most abundant in Station 1 while the least was observed in Station 3. The highest number of swimmers were recorded in Station 5 while none was recorded in Stations 1 and 6. Station 5 also had the highest count of sprawlers while the least number was recorded in Station 3.

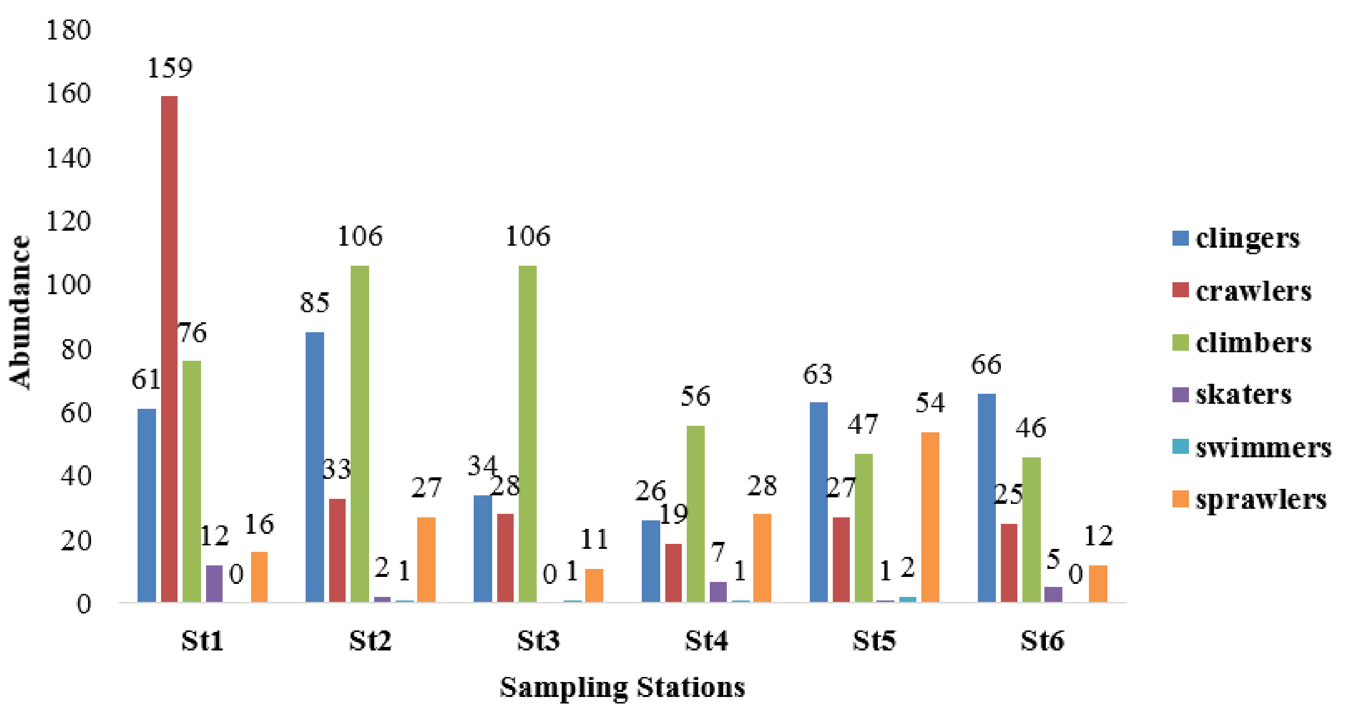


**Figure 2: Spatial distribution of functional groups based on Mode of Locomotion and Microhabitat Preference (MOL/MP) in Owena River, Southwestern Nigeria**

The temporal distribution of macroinvertebrates based on mode of locomotion and microhabitat preferences is presented in Figure 3. The highest number of clingers and skaters was recorded in December, 2024, while the least was in June, 2025. Similarly, swimmers was recorded to be the most abundant in December, 2024, while none was recorded in June, 2025 and September, 2024. The highest number of crawlers and sprawlers was recorded in March, 2025 while the least number was in September, 2024. The highest abundance of climbers was recorded in March, 2022 while the least was recorded in December, 2024.

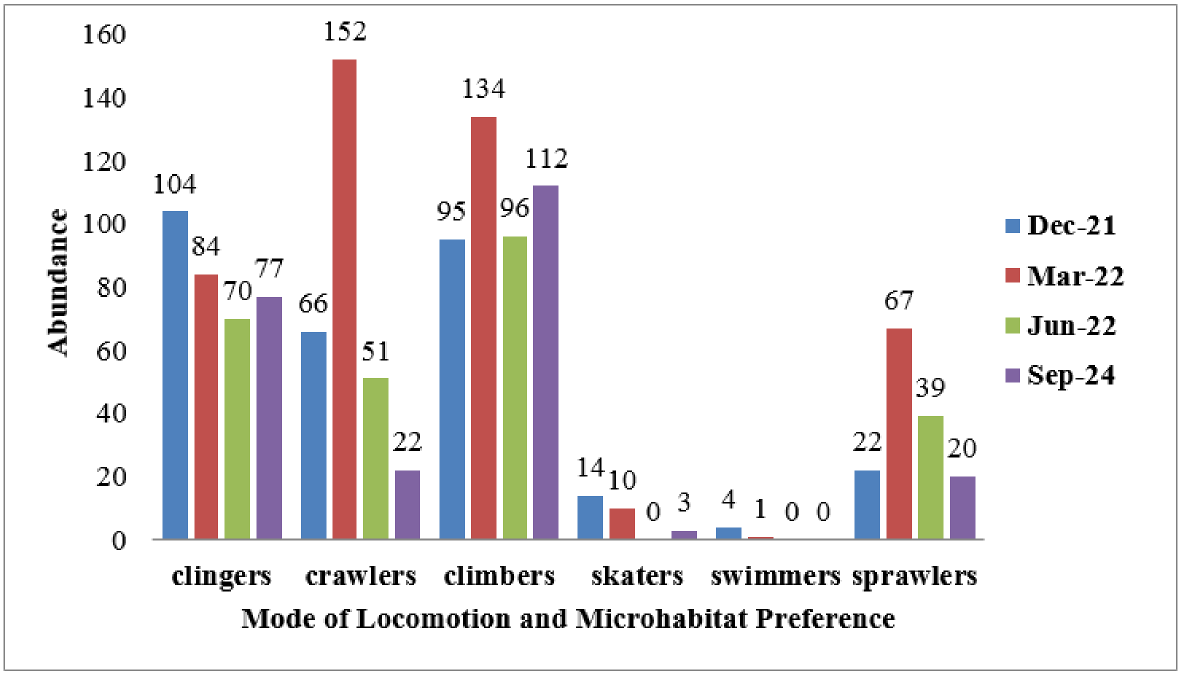


**Figure 3: Temporal distribution of functional groups based on Mode of Locomotion and Microhabitat Preference (MOL/MP) in Owena River, Southwestern Nigeria**

The seasonal distribution of locomotion groups is presented in figure 4. Total macroinvertebrate abundance was higher during the dry season (672 individuals) than during the wet season (571 individuals). Climbers showed the greatest seasonal difference, increasing from 214 individuals in the wet season to 264 individuals in the dry season. Crawlers increased from 147 individuals in the wet season to 180 individuals in the dry season, while clingers increased from 115 to 136 individuals. Swimmers showed a smaller increase from 59 individuals in the wet season to 62 individuals in the dry season. In contrast, burrowers were slightly more abundant in the wet season (36 individuals) than in the dry season (30 individuals).

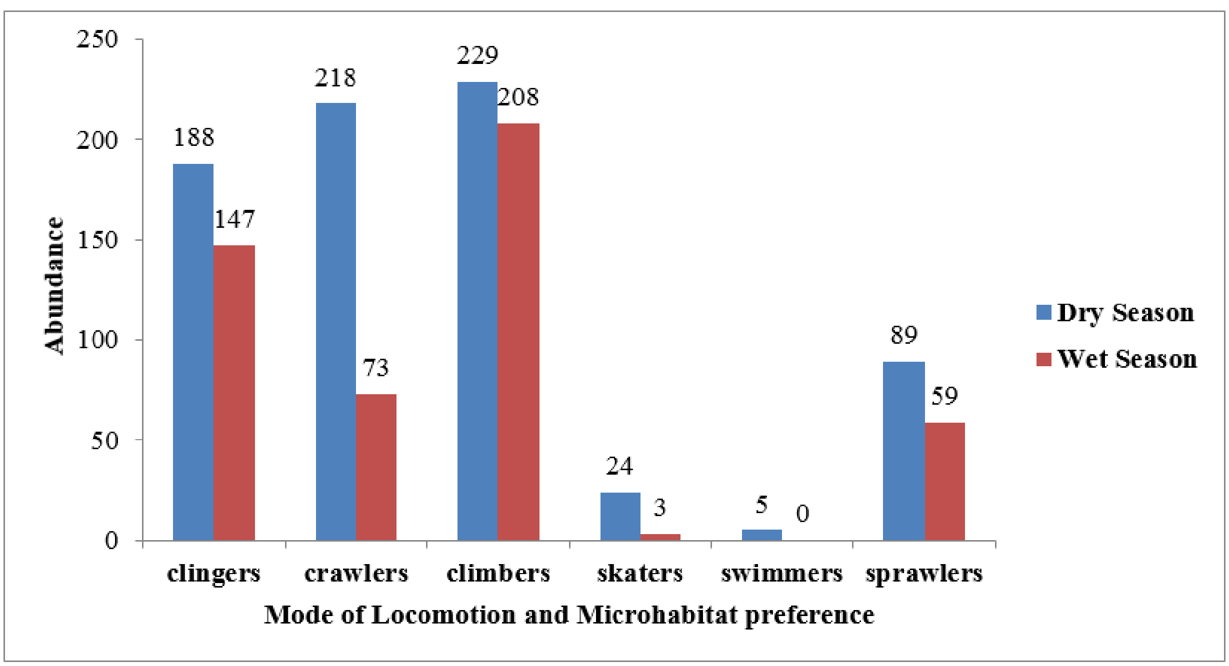


**Figure 4: Seasonal variation of functional groups based on Mode of Locomotion and microabitat Preference (MOL/MP) in Owena River, Southwestern Nigeria**

### 4.4 Relationship Between the Macroinvertebrates and the Physico-chemical Parameters of Owena River

Canonical Correspondence Analysis (CCA) tri-plot revealed significant relationship between the environmental variables and species abundance (Figure 5). Axis 1 of the CCA tri-plot accounted for 36.43% of the entire variations while axis 2 accounted for 15.43% of variation in data set. Macroinvertebrates in axis 1 were mostly related to TDS, EC, Alkalinity, Nitrate, Sulphate and pH while macroinvertebrates in axis 2 were related to Temperature, BOD, Phosphate and Calcium. The Organisms associated with Axis 1 of CCA include; *Afronurus* sp*.*, *Adenophlebiodes* sp., *Orectogyrus* sp., *Elassoneuria candida*, *Olpogastra lugubris*, *Rhagovelia* sp., *Limnogonus* sp., *Orectogyrus* sp*.* B., *Phyllomacromia* sp*.,* while macroinvertebrates associated with axis 2 of the CCA include; *Agriocnemis maclachlani*, *Bulinus* sp., *Helisoma* sp., *Crocothemis erythraea*, *Trithemis annulata*, *Urothemis assignata*, *Lanistes varicus*, and *Zygonoides* sp*.*

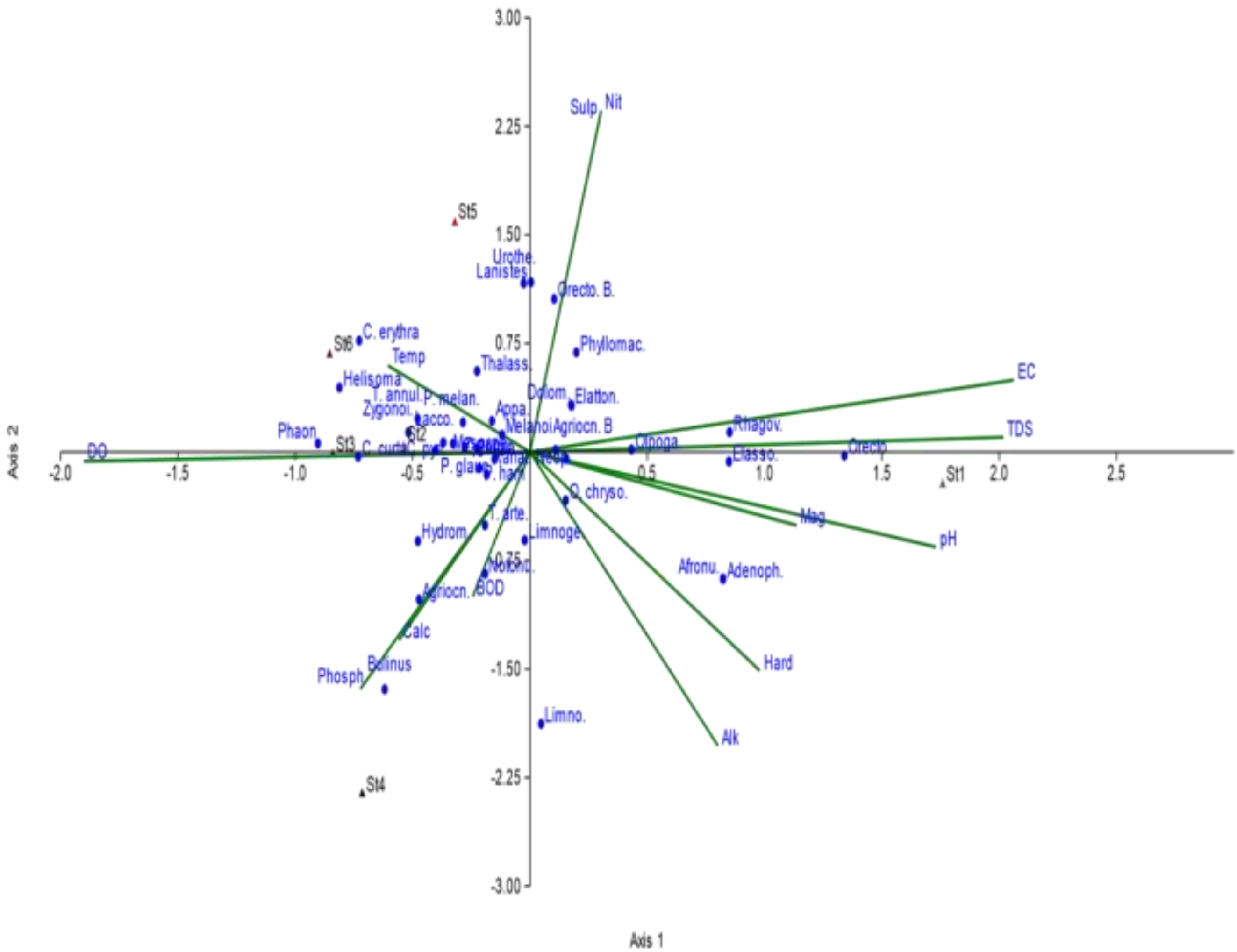


**Figure 5: Triplot of first and second CCA axes of macroinvertebrates, physico-chemical parameters and the sampling stations in Owena River, Southwestern Nigeria**

**Table 5: Eigen Value (Monte Carlo permutation test) of the first four axes of the canonical correspondence analysis of physico-chemical parameters and Macroinvertebrates in Owena River, Southwestern Nigeria**

| Axis | Eigenvalue | % of total inertia | P |
|---|---|---|---|
| 1 | 0.28466 | 36.43 | 0.605 |
| 2 | 0.12299 | 15.74 | 0.635 |
| 3 | 0.11605 | 14.85 | 0.025 |
| 4 | 0.091868 | 11.76 | 0.005 |

## 5.0 DISCUSSION

### 5.1 Physico-chemical characteristics of Owena River

The present study revealed that most physicochemical parameters of Owena River did not differ significantly among the sampling stations, indicating relatively similar environmental conditions along much of the river course. This observation agrees with the findings of Olaniyan and Akinkuolie (2016), who reported limited spatial variation in several water quality parameters in a tropical Nigerian river subjected to moderate anthropogenic influence. However, the significant spatial differences observed for sulphate and alkalinity suggest localized influences, possibly related to substrate composition, groundwater input, or human activities around particular stations. Dissolved oxygen was significantly higher during the wet season than during the dry season. This result is consistent with the findings of Olaniyan (2010) and Zhang *et al.* (2021), who reported increased dissolved oxygen concentrations during periods of higher discharge and enhanced aeration. The higher wet-season dissolved oxygen values in the present study may therefore be attributed to increased water turbulence, dilution, and atmospheric re-aeration associated with rainfall and runoff.

The pH values remained slightly alkaline and did not vary significantly between seasons. Similar relatively stable alkaline conditions have been reported in other tropical freshwater systems by Mohan and Latha (2013). The absence of significant seasonal variation suggests that the buffering capacity of the river was sufficient to resist major acid-base fluctuations despite seasonal changes in runoff and water volume. Total dissolved solids increased significantly during the wet season. This finding agrees with the observations of Zhang *et al*. (2021), who reported that rainfall and catchment runoff increase the transport of dissolved minerals and other materials into river systems. The simultaneous increase in electrical conductivity supports this interpretation because conductivity is closely related to the concentration of dissolved ions. A similar positive relationship between TDS and conductivity has been reported for Nigerian rivers by Amusan *et al.* (2018).

Temperature was significantly higher during the dry season. This pattern is in agreement with the findings of Kumar *et al*. (2022) and Akindele *et al*. (2014), who observed elevated dry-season temperatures in tropical rivers due to reduced cloud cover, increased solar radiation, and lower water volume. The lower wet-season temperatures recorded in the present study were likely influenced by rainfall, increased flow, and greater dilution. Biochemical oxygen demand was markedly higher during the dry season. This result corroborates the findings of Amusan *et al*. (2018), who reported increased BOD during low-flow conditions when organic matter becomes more concentrated and microbial decomposition intensifies. The lower BOD values observed during the wet season in the present study may therefore reflect dilution and flushing of organic materials by increased discharge.

Phosphate concentration increased significantly during the wet season, indicating enhanced nutrient input from surrounding land-use activities. This observation is similar to the findings of Mateo-Sagasta *et al*. (2017), who reported that agricultural runoff and surface wash are major sources of phosphate enrichment in freshwater ecosystems. Although the phosphate values recorded in the present study were not extremely high, their seasonal increase suggests that rainfall events contribute substantially to nutrient transport within the Owena River catchment. Magnesium and calcium concentrations were also significantly higher during the wet season. Comparable increases in divalent cations during periods of high runoff were reported by Zhang *et al*. (2021) and were attributed to increased weathering and leaching of minerals from soils and rocks. The higher calcium concentration relative to magnesium in the present study contributed to the observed increase in water hardness.

Sulphate showed significant spatial variation but no significant seasonal variation. A similar pattern was reported by Olaniyan and Akinkuolie (2016), who suggested that sulphate distribution in tropical rivers may be controlled more by localized geological or anthropogenic sources than by seasonal hydrological processes. Nitrate concentration increased during the wet season, although the seasonal difference was not statistically significant. The temporal peak recorded in September suggests episodic nutrient input associated with rainfall and runoff. Similar wet-season increases in nitrate have been reported in agricultural catchments by Mateo-Sagasta *et al*. (2017). Water hardness was significantly higher during the wet season. This finding agrees with the observations of Mohan and Latha (2013), who associated increased hardness with elevated calcium and magnesium concentrations. The hardness values obtained in the present study indicate that Owena River can be classified as moderately hard water.

**5.2 Macroinvertebrate community composition**

The macroinvertebrates obtained in the present study are comparable to many other Nigerian inland waterbodies in terms of species composition and abundance. Similar assemblages have been reported by Olaniyan *et al*. (2019) on Oluwa River, Iyiola and Asiedu (2020) on Ogunpa River, and Omovoh *et al.* (2022) on Wupa River. The present findings also compare favourably with studies conducted outside Nigeria, such as Malakane *et al*. (2020) on Blyde River, South Africa, and Karim *et al*. (2021) on River Zhob, Pakistan. The relatively high number of taxa recorded in Owena River suggests that the river is comparatively rich in macroinvertebrate diversity when compared with previous studies on similar freshwater systems, including Akindele *et al*. (2019) on Osun River, Anyanwu *et al*. (2019) on Ossah River, Amusan and Abubakar (2023) on Aro and Ewure Rivers, and Gao *et al*. (2023) on urban rivers in China.

The relatively high abundance and diversity of macroinvertebrates observed in this study may be attributed to factors such as water quality, nutrient availability, the presence of predator species, and the level of competition among organisms. A similar explanation was provided by Aliu *et al.* (2020), who reported that environmental quality and resource availability are important determinants of macroinvertebrate abundance in freshwater ecosystems. The variations in abundance and taxonomic composition among the sampling stations further suggest differences in habitat quality across the river, which agrees with the findings of Aduwo *et al.* (2019) that habitat heterogeneity strongly influences macroinvertebrate distribution. Runoff from agricultural lands within the Owena River catchment may have contributed to changes in water quality and habitat structure, thereby influencing the observed spatial differences in macroinvertebrate diversity and abundance. The occurrence of Odonata, Sorbeoconcha, and Hemiptera in all sampling stations suggests the possible presence of mild pollution within the river. These groups have previously been reported as indicators of mildly polluted aquatic environments by Mohammed *et al.* (2020).

Odonata was the dominant order in the present study. This finding is consistent with previous reports from Nigerian freshwater systems where odonates were also dominant (Akawo *et al.,* 2021; Amusan, 2023). The high abundance of Odonata may be related to their strong dispersal ability and capacity to colonize new habitats rapidly, as suggested by Mohammed *et al.* (2020). In addition, Adu *et al.* (2019) noted that odonates are effective habitat colonizers because of their adaptability and efficient reproductive strategies, which enable them to establish quickly and dominate favourable habitats. Their dominance may also be associated with their tolerance to a wide range of environmental conditions, including moderately polluted habitats, as reported by Paramita *et al.* (2015) and Žganec *et al*. (2020). The abundance of *Sorbeoconcha* sp., which is known to be pollution tolerant, may indicate the presence of organic pollution associated with decomposing organic matter in the river. Similar observations were made by Iyiola and Asiedu (2020), who reported that pollution-tolerant gastropods are often abundant in contaminated freshwater environments. The widespread occurrence of hemipterans in all stations may be related to the availability of food resources, particularly chironomids, oligochaetes, and periphyton, which are commonly associated with nutrient-rich environments (Akawo *et al.,* 2021).

The low abundance of sensitive insect groups such as Ephemeroptera, Plecoptera, and Trichoptera (EPT) suggests some level of pollution or ecological disturbance in the river. Sensitive EPT taxa are generally abundant and diverse in clean and well-oxygenated waters (Mohammed *et al*., 2020). Similar reductions in EPT abundance have been reported from comparable landscapes by Karim *et al*. (2021). The limited representation of these groups in the present study therefore supports the inference that Owena River may be experiencing moderate ecological stress. Members of Libellulidae were particularly abundant in the present study. This observation agrees with previous studies by Kemabonta *et al.* (2019), Adu *et al*. (2019), Mafuwe (2020) and Manu *et al.* (2022), all of which reported Libellulidae as the most abundant odonate family in different freshwater systems. The abundance of this family is not unexpected because libellulids are widely distributed and are known to tolerate a range of environmental conditions, including moderately polluted waters.

*Melanoides tuberculata* and *Pseudagrion hamoni* were recorded in large numbers across all sampling stations. The widespread distribution of Melanoides tuberculata is consistent with reports by Aduwo *et al.* (2019) and Abbati *et al.* (2020), who described this species as invasive and widely distributed in Nigerian freshwater bodies. Its abundance may be related to favourable habitat conditions within the different reaches of the river. *Pseudagrion hamoni* was the dominant taxon in the present study. Its abundance may be associated with the availability of suitable substrata and dense riparian vegetation, which provide favourable conditions for perching and oviposition. This finding agrees with Adu *et al*. (2022), who reported that *Pseudagrion hamoni* is widespread and common in West and East African freshwater systems. The present result also supports Kemabonta *et al.* (2019), who identified *Pseudagrion hamoni* as the most abundant species in Akwa Ibom River. However, it contrasts with the observation of Adu *et al.* (2022) in River Aponmu, Ondo State, where only few specimens of the species were recorded. The occurrence of *Orectogyrus sp.* in relatively high numbers is also consistent with previous studies by Camara *et al.* (2020) and Akinpelu *et al*. (2024), who reported large populations of this beetle in other freshwater habitats. According to Doeurk *et al.* (2023), the abundance of Orectogyrus is closely related to the availability of food resources and suitable substrata. Increased light penetration and the resulting enhancement of primary production may have contributed to its abundance in some stations, as suggested by Akinpelu *et al.* (2024).

Seasonally, more macroinvertebrates were recorded during the dry season than during the wet season. The lower abundance during the wet season may be due to increased water volume, altered flow characteristics and surface runoff, which can destabilize habitat structure and displace organisms from their microhabitats (Mohammed *et al.,* 2020). A similar explanation was proposed by Amusan *et al*. (2018), who linked reduced wet-season abundance to sediment instability and stormwater influx. The present result is consistent with reports of higher dry-season abundance and diversity in other Nigerian and West African freshwater systems, including Aduwo *et al*. (2019), Mohammed *et al.* (2020), Addo-Bediako (2020), and Adeleke *et a*l. (2024).

### 5.3 Relationship between locomotion groups and physicochemical variables

The results of the canonical correspondence analysis (CCA) indicated a strong correlation between the macroinvertebrates collected in this study and the environmental variables. This implied that the community structure of the macroinvertebrates was greatly influenced by the physico-chemical parameters of the water (Akindele *et al.,* 2019). The observed correlations indicate that changes in water quality and habitat conditions influenced the distribution and abundance of climbers, crawlers, clingers, swimmers, and burrowers. Similar relationships between environmental variables and macroinvertebrate functional organization have been reported in freshwater ecosystems by Kemabonta *et al.* (2019) and Mohammed *et al.* (2020).

## 6.0 CONCLUSION

The significant relationships observed between locomotion groups and physicochemical variables indicate that the functional structure of the macroinvertebrate community is responsive to changes in water quality and habitat conditions. The predominance of vegetation-associated taxa, together with the reduced representation of sensitive EPT taxa, suggests that Owena River still retains considerable habitat heterogeneity but is experiencing moderate anthropogenic influence associated with nutrient enrichment, organic inputs, and localized habitat disturbance.

## 7.0 RECOMMENDATIONS

The findings of this study have important implications for the management and conservation of Owena River. The dominance of vegetation-associated macroinvertebrates and the significant relationships between locomotion groups and physicochemical variables indicate that habitat structure and water quality are critical determinants of ecological condition in the river. To maintain and improve the ecological integrity of Owena River, the following measures are recommended:

- Riparian and aquatic vegetation should be protected from indiscriminate clearing because it provides essential habitat, food resources, attachment surfaces and breeding sites for macroinvertebrates.
- Nutrient and sediment inputs from surrounding agricultural lands should be reduced through the adoption of buffer strips, controlled fertilizer application and erosion-control practices.
- Domestic and other organic wastes should be prevented from entering the river in order to minimize biochemical oxygen demand and maintain adequate dissolved oxygen levels.
- Activities that alter substrate composition, increase sediment deposition, or reduce habitat heterogeneity should be carefully managed, particularly in downstream sections of the river.
- Long-term monitoring programmes should integrate physicochemical measurements with both taxonomic and functional macroinvertebrate indicators, including locomotion and microhabitat preference groups, to provide early detection of ecological change.
- Community-based awareness programmes and integrated watershed management strategies should be promoted to encourage sustainable use of river resources and reduce anthropogenic pressure on the ecosystem.

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