

Spatio-temporal Dynamics of Physico-Chemical Hydrology and Aquatic Insect Assemblages in a Western Nigerian River: A Canonical Correspondence Approach to Ecological Integrity

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Abstract

This study evaluated the interconnected dynamics of water physico-chemical parameters and aquatic insects within the Omi River, a perennial lotic system in the Iwajowa Local Government Area of Oyo State, Western Nigeria. Sampling was conducted across five stations over an annual cycle spanning December 2024 to September 2025 to capture seasonal variations. Physico-chemical water properties and hydromorphological variables were monitored alongside an inventory of resident aquatic insect communities. A total of 1,040 individuals belonging to 6 orders, 19 families, and 44 genera were cataloged, exhibiting a strong dominance of *Rhagovelia* sp. (24.04%). Spatial analysis revealed high environmental uniformity across all stations, with biological oxygen demand (BOD) being the only parameter to show significant spatial variation ($p < 0.05$) due to mild downstream organic enrichment at Station 5. Conversely, the bimodal tropical climate drove sharp seasonal fluctuations. River width, depth, volumetric discharge, turbidity and dissolved oxygen (DO) significantly peaked during the wet season ($p < 0.001$), while total dissolved solids (TDS) and electrical conductivity (EC) concentrated significantly during the dry season ($p < 0.001$). Total abundance and diversity metrics peaked in the stable dry season, while individual EPT numbers surged during wet-season aeration. Canonical Correspondence Analysis (CCA) demonstrated that hydromorphological attributes (discharge, depth, stream width, turbidity) were the primary ecological forces structuring species distribution, overwhelming nutrient gradients. The study concluded that, the Omi River retains high biological integrity as at the time this study was conducted, providing a crucial baseline framework for West African freshwater conservation.

INTRODUCTION

Freshwater ecosystems are vital planetary life-support systems that provide critical ecological goods and services, regulate regional climate regimes and harbour exceptional levels of global biodiversity (Edegbene et al., 2024). Despite their immense ecological and socio-economic value, lotic systems such as rivers and streams are increasingly recognized as some of the most vulnerable and degraded habitats worldwide. Under the anthropocene epoch, global river networks are subjected to unprecedented systemic pressures driven by rapid urbanization, agricultural expansion and industrial effluent discharge. In tropical regions, particularly within developing sub-Saharan African nations, these stressors are heavily magnified by weak environmental regulation and severe demographic pressures, leading to the rapid alteration of river hydrology and the degradation of overall ecological integrity (Mohammed, 2026).

In West Africa, the guinea savanna and transition forest zones of Western Nigeria stand out as critical geographical regions where aquatic systems face severe, multi-faceted environmental strain (Olatunji and Odedeyi, 2023). A prime example is the Omi River, a vital lotic network flowing through Iwajowa Local Government Area (LGA) in Oyo State, Nigeria. The unique socio-economic landscape of this agrarian zone introduces distinct anthropogenic gradients into the river channel. Rivers in this part of Western Nigeria are increasingly subjected to complex chemical and physical alterations driven by extensive rain-fed agricultural practices, including widespread cassava, yam and maize cultivation, alongside shifting land-use patterns like riparian forest clearing and intense cattle grazing. These localized perturbations contribute significant non-point source nutrient loads and siltation, shifting critical water quality parameters such as dissolved oxygen dynamics, electrical conductivity, pH and nutrient concentrations (nitrates and phosphates) and creating a highly volatile, fluctuating environment for aquatic life (Olowo et al., 2025).

Compounding these anthropogenic stressors are the profound spatio-temporal variations dictated by the region's distinct tropical climate. The hydrology of the Omi River is structurally divided by a bimodal rainfall pattern consisting of an intense wet season (spanning from April to October) and a severe dry season from November to

March. During the peak rainy season, heavy precipitation induces massive storm water runoff from the surrounding agricultural catchments, resulting in severe bank erosion, increased sediment load and the physical dilution of chemical parameters (Akawo, 2023). Conversely, the dry season triggers drastic reductions in river discharge and flow velocity, concentrating nutrients, lowering dissolved oxygen thresholds, and fundamentally altering benthic micro-habitat availability (Mohammed, 2026). The interaction between these sharp seasonal transitions and localized human activities creates highly complex, dynamic environmental matrices within this river channel.

To accurately assess the ecological health of such a dynamic system, traditional, isolated chemical water sampling is widely recognized as insufficient. Chemical monitoring only provides a single snapshot of water quality at the exact moment of collection, frequently failing to capture transient or pulse-pollution events. Consequently, modern biological monitoring utilizing aquatic macroinvertebrates specifically aquatic insect assemblages has emerged as a foundational approach in tropical limnology (Adeleke and amusan, 2024). Aquatic insects are exceptional bioindicators of ecological integrity due to their relatively sedentary lifestyles, well-documented sensitivities to environmental stress, and diverse functional roles within the aquatic food web (Arimoro et al., 2024). Shifts in the structural composition, taxonomic richness and functional traits of insect assemblages mirror the long-term, integrated impacts of water quality degradation and physical habitat alteration (Enabulele and Olomukoro, 2024; Mohammed, 2026).

While the utility of macroinvertebrates as bioindicators is widely acknowledged, their specific spatial and temporal responses to compounding hydrological variations in Western Nigerian rivers and particularly within the Omi River system in Iwajowa L.G.A. remain insufficiently integrated into regional conservation frameworks. Prior regional studies have frequently relied on descriptive, univariable statistical indices that fail to map the mathematically complex, direct relationships between community structure and environmental variables (Akindele et al., 2023; Edegbene et al., 2023; Olowo et al., 2025). Multivariate ordination techniques, specifically Canonical Correspondence Analysis (CCA), provide a robust, non-linear approach to directly constrain biological assemblage data by corresponding environmental matrices. However, there remains a critical research gap in applying constrained ordination to map how highly localized, tropical agricultural pressures interact with extreme seasonal flow changes to reshape the niche space of sensitive insect orders (such as Ephemeroptera, Plecoptera, and Trichoptera) versus tolerant taxa (such as Chironomidae). Without quantifying these precise, multidimensional socio-ecological relationships, developing effective, localized biotic indices for Nigerian river management remains functionally impossible (Edegbene, 2021; Edegbene et al., 2024).

To address this critical environmental and analytical gap, this study focuses on evaluating the interconnected dynamics of water chemistry and aquatic macroinvertebrates within this vital, yet heavily impacted fluvial system. The primary objective of this research is to investigate the spatio-temporal dynamics of physico-chemical hydrology and aquatic insect assemblages across distinct anthropogenic gradients in the Omi River, Iwajowa LGA, Oyo State, Nigeria, using a Canonical Correspondence Approach. Specifically, this study aims to: (i) characterise the seasonal and spatial variations in key hydrological and nutrient parameters along the river's course; (ii) inventory the taxonomic composition, abundance, and functional structures of the resident aquatic insect communities; and (iii) apply CCA to model the precise environmental drivers that dictate insect community distribution. By linking multivariate environmental matrices directly to biological indicators, this study seeks to diagnose the current state of the river's ecological integrity, thereby providing a robust, statistically validated framework to guide targeted river restoration, water policy formulation, and biodiversity conservation in West African lotic ecosystems.

Materials and Methods

2.1 Study Area

The study was conducted on the Omi River, which originates within the mountainous headwaters of Inanyin settlement traverses through Iwere-ile in Iwajowa Local Government Area, Oyo State Nigeria. Iwajowa is located in the Oke-Ogun region in northwestern part of Oyo State, sharing a border with the Benin Republic. The L.G.A lies approximately between Latitude 7°30' to 8°00'N and Longitude 2°45' to 3°30'E, covering an estimated area of about 2,529 km² (Fig. 1). Due to its geographic location and years of agricultural activities such as slash and burn farming practices, its primary vegetation is classified as Derived Savanna which is characterized by a tropical savanna climate (Koppen Aw classification) defined by a pronounced seasonal dichotomy. The monsoonal wet season commences in April and terminates in October yielding roughly 90% of regional's annual precipitation, which historically varies between 1,100 mm and 1,400 mm (IITA, 2010). This wet period is succeeded by a severe dry season from November to March, dictated by the dry, dust-laden Northeast Trade Winds (Akinbode et al., 2008). Atmospheric Moisture levels track the seasonal variations, causing relative humidity to remain high and oppressive during the wet season, hovering between 80% and 88%, but fall dramatically to lows of 30% to 40% at the peak of the dry season, compounding regional water stress (NiMet, 2025). The study site has rich biodiversity ranging from flora to fauna. Some notable floral diversity within Iwajowa forest-savanna zone are *Vitellaria paradoxa* (Shea Butter Tree), *Parkia biglobosa* (African Locust Bean), *Anogeissus leiocarpus* (African Birch) known locally as *Ayin*, *Daniellia oliveri* (West African Copaiba Balsam) locally known as *Iya*, *Triplochiton scleroxylon* (Obeche), *Milicia excels* (Iroko), *Khaya senegalensis* (African mahogany) and *Ceiba pentandra* (Silk Cotton Tree) (Ogidan, et al., 2023). While some dominant faunae are *Philantomba Maxwellii*, *Erythrocebus patas*, *Chlorocebus sabaeus*, *Thryonomys swinderianus*, *ploceus cucullatus*, *python sabaes*, *Naja nigrocollis* and *Varanus niloticus*. Omi River flows from the outskirts of Ayetoro town to Ilaji-Ile, before extending into the dense forest zone near the Nigeria-Benin border. The river maintains perennial flow characteristics and supports domestic, agricultural and small-scale fishing activities within the local communities. Anthropogenic activities observed around Omi River include commercial farming, grazing, charcoal production, deforestation, and cassava processing facilities, discharge of industrial effluents, washing, bathing and fishing activities. The river substratum is predominantly composed of fine sand mixture with mud, pebbles, debris and decaying organic matter further contributing to its aquatic insect compositions.

2.2 Sampling Programme

To evaluate seasonal dynamics and spatial heterogeneity within the Omi River, a spatio-temporal survey design was employed. Five sampling stations were selected along the river stretch, covering representative reaches and distinct microhabitats. Sampling was executed tri-monthly across 12-month duration, capturing both the wet and dry seasons over an annual cycle. This systematic framework ensured that structural variations in water quality and aquatic insect communities were robustly accounted for.

2.3 Collection of Water Samples

Prior to water and biological sampling, river hydrological profiling and *in-situ* physico-chemical parameters were determined directly to prevent disturbance-induced bias. Surface water temperature, dissolved oxygen (DO), pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured using calibrated digital multi-function meter and turbidity was quantified on-site using a calibrated turbidity tube. Concurrently, channel width and depth were measured using a standardized steel measuring tape to calculate cross-sectional area and subsequent river discharge, while flow velocity was determined via the float method by timing a buoyant object over a pre-measured distance. Following these measurements, sub-surface water samples were collected at a depth of approximately 20–30 cm in sterile 1 L polyethylene bottles for the laboratory analysis using standard techniques. Samples for

biochemical oxygen demand (BOD₅) were collected in specialized 250 ml amber glass bottles. All collected samples were stored in an ice-filled cooler box at approximately 4°C and transported to the laboratory for analysis within 24 hours.

2.4 Collection, Sorting and Identification of Aquatic Insects

Aquatic insects were collected thrice per sampling station using a long-handled D-frame net and direct hand picking method. This net was used to scoop the open water, submerged and emergent vegetation zones in the river. The sorting of the collected specimens was done on a white enamel tray. Sorted specimens were preserved in specimen bottles containing 70% ethanol solution (APHA, 2005) and appropriately labeled. In the laboratory, the preserved samples were thoroughly rinsed through a 500 µm sieve to remove fine sediment and taxonomically identified to the possible lowest level using standard dichotomous regional identification keys under a digital microscope (TEMLOV-DM9PRO).

2.5 Statistical Analysis

Statistical analyses were performed to evaluate the spatial and temporal variations in water quality parameters and aquatic insect assemblages. Prior to parametric testing, data were subjected to the Shapiro-Wilk test for normality and Levene's test for homogeneity of variance. A one-way Analysis of Variance (ANOVA) was executed to determine significant spatial variations in the mean values of physico-chemical and hydrological parameters across the sampling stations, while an independent-samples t-test was employed to evaluate temporal variations between the wet and dry seasons. To assess community structure, structural attributes were quantified using standard diversity indices—including the Shannon-Wiener diversity index (H'), Margalef's richness index (d), Simpson's dominance index (D), and Pielou's evenness index (J') alongside the Biological Monitoring Working Party Scoring System for South Africa (BMWP-SA) to determine the biotic integrity of the waterbodies. To evaluate the relationships between environmental conditions and the aquatic insect communities, Canonical Correspondence Analysis (CCA) was performed using a direct gradient ordination technique. Biological abundance data were log-transformed ($\log_{10}(x + 1)$) prior to ordination to down-weight dominant taxa, and rare species contributing less than 2% to the total abundance were excluded. The significance of the extracted canonical axes and species-environment correlations was validated using a Monte Carlo permutation test with 999 permutations. All univariate and multivariate statistical procedures were executed using PAST (Paleontological Statistics, Version 4.13) and R software environments, with statistical significance established at $p < 0.05$.

Results

3.1 Spatial Dynamics of Water Quality and Environmental Uniformity

The spatial analysis of the physico-chemical and nutrient properties of the Omi River across the five sampling stations reveals distinct longitudinal fluctuations in the mean concentrations of each parameter (Table 1). Water temperature reached its highest mean level at Station 2 and dropped to its lowest mean value at Station 4. Physical channel dimensions varied across the monitoring grid, with stream width peaking at Station 3 and narrowing to its lowest mean extent at Stations 2 and 4. Channel depth was highest at Station 1 and reached its lowest mean level at Station 4. Volumetric water discharge peaked at Station 5 and was lowest at Station 2, while flow velocity reached its maximum mean rate at Station 4 and remained at a lower, uniform mean rate across all other stations. Indicators of suspended and dissolved materials also varied spatially across the sampling sectors. Turbidity was

highest at Station 4 and lowest at Station 3. Both total dissolved solids and electrical conductivity followed identical spatial trends, peaking at Station 5 and dropping to their lowest mean concentrations at Station 2. Dissolved oxygen concentrations were highest at Station 2 and fell to their lowest mean level at Station 5. Conversely, biochemical oxygen demand reached its highest mean level at Station 5 and was lowest at Station 3. Nutrient and ionic profiles showed localized peaks and troughs across the river stretch. Nitrate concentrations were highest at Station 2 and lowest at Station 5, whereas phosphate concentrations reached their maximum mean level at Station 5 and dropped to their lowest mean level at Station 4. Water pH values trended from their highest mean level at Station 4 to their lowest mean level at Station 3. Calcium concentrations peaked at Station 4 and were lowest at Station 5. Finally, both magnesium concentrations and total water hardness exhibited identical spatial distributions, reaching their highest mean values at Station 4 and dropping to their lowest mean levels at Station 5.

Table 1
Spatial Variation of Physico-chemical and Nutrient Parameters along Omi River, Iwajowa Local Government Area, Oyo State, Nigeria from December 2024 to September 2025

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	F-value	p-value
Temperature (°C)	28.52 ± 0.52	28.70 ± 0.61	28.00 ± 0.63	27.10 ± 0.84	28.23 ± 0.48	0.995	0.4402
Width (m)	13.00 ± 3.54	11.75 ± 2.93	14.25 ± 2.66	11.75 ± 3.71	14.00 ± 3.92	0.124	0.9716
Depth (m)	1.52 ± 0.37	1.23 ± 0.34	1.18 ± 0.38	1.10 ± 0.34	1.45 ± 0.39	0.255	0.9024
Flow Velocity (m s ⁻¹)	0.55 ± 0.03	0.55 ± 0.06	0.55 ± 0.03	0.62 ± 0.05	0.55 ± 0.03	0.628	0.65
Discharge (m ³ s ⁻¹)	12.79 ± 5.61	8.12 ± 3.01	10.74 ± 4.41	9.19 ± 4.14	13.39 ± 5.75	0.232	0.9158
Turbidity (NTU)	21.50 ± 5.95	22.00 ± 5.67	20.75 ± 6.49	23.25 ± 7.47	21.00 ± 6.49	0.024	0.9988
Dissolved Oxygen (mg L ⁻¹)	7.31 ± 0.40	7.36 ± 0.28	7.15 ± 0.37	6.85 ± 0.50	6.79 ± 0.43	0.42	0.7918
pH	6.91 ± 0.29	7.12 ± 0.08	6.85 ± 0.24	7.54 ± 0.05	7.42 ± 0.05	2.94	0.0559
TDS (mg L ⁻¹)	64.00 ± 6.75	62.75 ± 6.69	74.75 ± 13.24	67.50 ± 9.36	76.75 ± 8.62	0.466	0.7598
EC (µS cm ⁻¹)	136.50 ± 11.32	124.50 ± 14.13	151.75 ± 28.75	148.75 ± 24.94	150.50 ± 23.18	0.296	0.8758
BOD (mg L ⁻¹)	1.10 ± 0.18	1.17 ± 0.07	0.91 ± 0.08	1.21 ± 0.12	1.73 ± 0.30	3.3	0.0396
Nitrate (mg L ⁻¹)	1.34 ± 0.66	2.92 ± 2.62	1.57 ± 1.22	0.65 ± 0.58	0.64 ± 0.56	0.461	0.7635
Phosp.hate (mg L ⁻¹)	0.10 ± 0.04	0.07 ± 0.03	0.11 ± 0.04	0.06 ± 0.03	0.21 ± 0.09	1.488	0.2552
Calcium (mg L ⁻¹)	13.24 ± 1.86	13.74 ± 1.86	13.84 ± 2.57	14.81 ± 1.75	11.57 ± 1.00	0.403	0.8034
Magnesium (mg L ⁻¹)	18.89 ± 4.42	30.14 ± 9.35	30.43 ± 15.93	30.96 ± 18.05	16.14 ± 4.48	0.366	0.8291
Water Hardness (mg L ⁻¹)	111.00 ± 22.74	158.25 ± 36.70	159.75 ± 61.04	164.50 ± 78.73	97.50 ± 15.97	0.41	0.7984
Significance: * indicates p < 0.05, **indicates p < 0.01 and *** show significant at P < 0.001							

3.2 Seasonal Hydrological Drivers in Tropical Catchments

The seasonal assessment of the environmental metrics of the Omi River demonstrates strong temporal fluctuations between the dry and wet seasons (Table 2). Water temperature recorded its highest mean level during the dry season and dropped to its lowest mean level during the wet season, although this shift was not statistically significant. Physical morphometric parameters changed substantially, with stream width, channel depth and volumetric water discharge all reaching their highest mean values in the wet season and falling to their lowest mean levels during the dry season, changes that were highly significant (p < 0.001). Conversely, flow velocity peaked at its

highest mean rate during the dry season and reached its lowest mean rate during the wet season. Chemical properties and dissolved mineral parameters also exhibited pronounced seasonal partitioning. Turbidity and dissolved oxygen concentrations both reached their highest mean values during the wet season and dropped to their lowest mean levels in the dry season, showing highly significant temporal differences ($p < 0.001$). In contrast, total dissolved solids and electrical conductivity followed an inverse trajectory, peaking at their highest mean concentrations during the dry season and declining to their lowest mean values during the wet season ($p < 0.001$). Water pH and biochemical oxygen demand both reached their highest mean values during the wet season and their lowest mean values during the dry season, but neither parameter showed a statistically significant seasonal shift. Nutrient and ionic factors demonstrated variable seasonal dynamics across the study period. Nitrate and phosphate concentrations both reached their highest mean concentrations during the wet season and dropped to their lowest mean levels during the dry season. Among the alkaline earth metals, calcium concentrations reached their highest mean level during the dry season and fell to their lowest mean level during the wet season, exhibiting a significant seasonal difference ($p < 0.01$). In contrast, magnesium concentrations and total water hardness both reached their highest mean values during the wet season and dropped to their lowest mean levels during the dry season, though these variations did not achieve statistical significance.

Table 2
Seasonal Variation of Physico-chemical and Nutrient Parameters along Omi River, Iwajowa Local Government Area, Oyo State, Nigeria from December 2024 to September 2025

Parameter	Dry	Wet	T-test	p-Value
Temperature (°C)	28.12 ± 0.53	28.10 ± 0.23	0.035	0.9729
Width (m)	7.80 ± 0.80	18.10 ± 1.16	-7.314	0.001***
Depth (m)	0.73 ± 0.09	1.86 ± 0.12	-7.46	0.001***
Flow Velocity (m s ⁻¹)	0.60 ± 0.03	0.53 ± 0.02	2.09	0.0516
Discharge (m ³ s ⁻¹)	3.70 ± 0.72	17.99 ± 1.93	-6.944	0.001***
Turbidity (NTU)	11.90 ± 1.22	31.50 ± 2.24	-7.685	0.001***
Dissolved Oxygen (mg L ⁻¹)	6.50 ± 0.19	7.69 ± 0.05	-5.931	0.001***
pH	7.15 ± 0.14	7.19 ± 0.14	-0.233	0.8184
TDS (mg L ⁻¹)	81.20 ± 5.18	57.10 ± 2.23	4.273	0.001***
EC (µS cm ⁻¹)	169.60 ± 11.67	115.20 ± 5.67	4.191	0.0011***
BOD (mg L ⁻¹)	1.16 ± 0.10	1.30 ± 0.16	-0.75	0.4644
Nitrate (mg L ⁻¹)	0.37 ± 0.15	2.48 ± 1.07	-1.956	0.081
Phosphate (mg L ⁻¹)	0.09 ± 0.03	0.13 ± 0.04	-0.672	0.5108
Calcium (mg L ⁻¹)	15.31 ± 0.78	11.57 ± 1.10	2.767	0.0136**
Magnesium (mg L ⁻¹)	19.21 ± 2.36	31.41 ± 9.46	-1.251	0.239
Water Hardness (mg L ⁻¹)	118.20 ± 10.63	158.20 ± 39.75	-0.972	0.3533
Significance: * indicates $p < 0.05$, **indicates $p < 0.01$ and *** show significant at $P < 0.001$				

3.3 Compositions and Relative Abundance of Aquatic Insects of Omi River

The taxonomic assessment of the aquatic insects along the Omi River cataloged a total of 1040 individuals. This entire biological assemblage belongs to a single taxonomic class (Insecta), which is structurally partitioned across 6 distinct orders, 19 separate families and 44 unique genera (Table 3). Looking at total community numbers, individual abundance reached its maximum at Station 1 and dropped to its lowest overall level at Station 4. Among the individual taxonomic groups, *Rhagovelia* sp. emerged as the most dominant taxon across the entire study river, reaching its highest mean density at Station 1 and its lowest concentration at Station 4. Other highly abundant groups showed distinct spatial preferences. For instance, *Pseudagrion* spp. reached its highest mean level at Station 2 and fell to its lowest level at Station 3, while *Orthetrum* sp. also peaked at Station 2 but dropped to its lowest representation at Station 5. *Orectogyrus* spp. and *Dineutus* sp. both exhibited their maximum abundance at Station 1, with *Orectogyrus* spp. falling to its lowest numbers at Station 3 and *Dineutus* sp. disappearing entirely at Station 4. Similarly, *Hydrochara* sp. reached its highest abundance at Station 2 and dropped to its lowest level at Station 1. In contrast, several intermediate and rare taxa were highly restricted or patchily distributed along the river channel. *Elassoneuria* sp. reached its highest mean level at Station 3 and fell to its lowest level at Station 1. Moderate pollution-tolerant groups such as *Sphaerodema* sp. peaked at Station 4 and dropped to their lowest abundance at Station 1, while *Eurymetra* sp. also reached its highest level at Station 4 but was entirely absent from Stations 3 and 5. Sensitive predatory groups like *Neoperla* sp. reached their highest concentration at Station 5 and were absent at Station 4. Many rare taxa occurred in exceptionally low numbers and were confined to single locations; for example, *Potamodytes* sp. and *Limnichus* sp. were found exclusively at Station 5, *Chironomus* sp. and *Caenis* sp. occurred only at Station 2, and *Adenophlebia* sp. was restricted entirely to Station 1.

Table 3
Compositions and Relative Abundance of Aquatic Insects along Omi River, Iwajowa Local Government Area, Oyo State, Nigeria from December 2024 to September 2025

Order	Family	Taxa	St 1	St 2	St 3	St 4	St 5	Tot.Abu.	Rel. Abu %)
Coleoptera	Dytiscidae	<i>Derovatellus sp.</i>	0	2	1	0	0	3	0.29
		<i>Philodytes sp.</i>	0	1	1	0	0	2	0.19
		<i>Hydrocanthus sp.</i>	0	0	0	0	1	1	0.10
	Gyrinidae	<i>Aulonogyrus sp.</i>	16	16	1	0	0	33	3.17
		<i>Orectogyrus spp.</i>	62	19	1	4	6	92	8.85
		<i>Dineutus sp.</i>	42	2	24	0	8	76	7.31
	Hydrophilidae	<i>Amphiops sp.</i>	4	0	2	0	0	6	0.58
		<i>Helochaeres sp.</i>	1	1	3	0	0	5	0.48
		<i>Hydrochara sp.</i>	1	46	4	1	2	54	5.19
		<i>Philaccolus sp.</i>	3	2	2	0	0	7	0.67
	Elmidae	<i>Potamodytes sp.</i>	0	0	0	0	4	4	0.38
	Limnichidae	<i>Limnichus sp.</i>	0	0	3	0	0	3	0.29
Hemiptera	Scirtidae	<i>Elodes sp.</i>	0	0	2	0	0	2	0.19
	Belostomatidae	<i>Sphaerodema sp.</i>	0	1	0	0	0	1	0.10
	Gerridae	<i>Eurymetra sp.</i>	1	6	4	8	6	25	2.40
		<i>Limnogonus sp.</i>	9	4	0	11	0	24	2.31
		<i>Tenagogonus sp.</i>	3	0	1	3	0	7	0.67
	Hydrometridae	<i>Hydrometra sp.</i>	4	1	2	2	1	10	0.96
	Naucoridae	<i>Laccocoris sp.</i>	2	6	0	4	1	13	1.25
	Nepidae	<i>Laccotrephes sp.</i>	2	5	6	0	3	16	1.54
		<i>Ranatra sp.</i>	2	3	7	1	3	16	1.54
	Notonectidae	<i>Anisops sp.</i>	3	2	2	3	2	12	1.15
		<i>Enithares sp.</i>	2	2	2	3	2	11	1.06
		<i>Nychia sp.</i>	2	1	1	1	0	5	0.48
	Veliidae	<i>Rhagovelia sp.</i>	3	7	4	1	2	17	1.63

Order	Family	Taxa	St 1	St 2	St 3	St 4	St 5	Tot.Abu.	Rel. Abu %)
Odonata	Chlorocyphidae	<i>Chlorocypha sp.</i>	73	42	46	28	61	250	24.04
	Coenagrionidae	<i>Agriocnemis sp.</i>	8	2	3	0	3	16	1.54
		<i>Pseudagrion spp.</i>	0	3	3	3	1	10	0.96
	Gomphidae	<i>Lestinogomphus sp.</i>	13	38	11	24	16	102	9.81
		<i>Paragomphus sp.</i>	0	0	3	0	3	6	0.58
		<i>Phyllogomphus sp.</i>	1	2	0	1	1	5	0.48
	Libellulidae	<i>Bradinopyga sp.</i>	0	1	0	0	0	1	0.10
		<i>Nesiothemis sp.</i>	2	0	0	0	1	3	0.29
		<i>Orthetrum sp.</i>	0	5	0	0	6	11	1.06
		<i>Olpogastra sp.</i>	26	41	19	9	0	95	9.13
		<i>Trithemis sp.</i>	1	3	2	5	2	13	1.25
		<i>Zygonoidea sp.</i>	1	0	2	2	0	5	0.48
	Platycnemididae	<i>Elatoneura sp.</i>	0	2	0	0	1	3	0.29
Diptera	Chironomidae	<i>Chironomus sp.</i>	0	0	3	0	0	3	0.29
Ephemeroptera	Caenidae	<i>Caenis sp.</i>	0	1	0	0	0	1	0.10
	Leptophlebiidae	<i>Notonurus spp.</i>	2	1	0	0	1	4	0.38
		<i>Adenophlebia sp.</i>	2	0	0	0	0	2	0.19
	Oligoneuriidae	<i>Elassoneuria sp.</i>	1	6	33	1	8	49	4.71
Plecoptera	Perlidae	<i>Neoperla sp.</i>	1	2	5	0	8	16	1.54
Total			293	276	203	115	153	1040	100

3.4 Spatial Diversity and Biological Indices of Aquatic Insects of Omi River

The analysis of community structure and biotic integrity metrics for aquatic insects across the five monitoring stations displays distinct spatial gradients along the Omi River (Table 4). Total individual abundance reached its peak at Station 1 and declined to its lowest overall level at Station 4. Comprehensive generic richness was highest at Station 2 and lowest at Station 4. Community diversity, as evaluated via the Shannon–Wiener index, reached its maximum mean value at Station 3 and dropped to its lowest index level at Station 5. Similarly, Simpson's diversity index peaked at Station 2 and reached its minimum baseline calculation at Station 5. The distribution of individuals across the present taxa, assessed via Pielou's evenness index, was highest at Station 4 and lowest at Station 1. The

overall structural richness of the habitat, determined through the Margalef richness index, reached its highest value at Station 2 and fell to its lowest point at Station 4. Overarching family-level variety was identically high at Stations 2, 3 and 5, while dropping to its lowest richness profile at Station 4. Biotic integrity indices also reflected notable spatial trends. The Biological Monitoring Working Party score reached its maximum level at Station 3 and its lowest baseline at Station 4. The Average Score Per Taxon was highest at Station 1 and dropped to its lowest level at Station 4. Finally, both the raw number of individual EPT organisms and the corresponding percentage of EPT individuals reached their peak values at Station 3 and fell to their lowest comparative levels at Station 4.

Table 4
Spatial Diversity indices of Aquatic Insects in Omi River, Iwajowa Local Government Area, Oyo State, Nigeria from December 2024 to September 2025

Diversity Index	St 1	St 2	St 3	St 4	St 5
Total abundance (N)	293	276	203	115	153
Taxa richness (S)	30	33	31	20	26
Shannon–Wiener Index (H')	2.403	2.672	2.702	2.419	2.397
Simpson's Diversity (1 – D)	0.857	0.896	0.890	0.869	0.814
Pielou's Evenness (J')	0.706	0.764	0.787	0.808	0.736
Margalef Richness Index (d)	5.105	5.694	5.646	4.004	4.970
NO. of Families	16	17	17	12	17
BMWP	107	106	110	74	107
ASPT	6.69	6.24	6.47	6.17	6.29
Individual EPT	6	10	38	1	17
% EPT	2.05	3.62	18.72	0.87	11.11

3.4 Seasonal Diversity and Biological Indices of Aquatic Insects of Omi River

The seasonal comparison of community attributes and biotic scores reveals temporal shifts in the structure of the aquatic insect assemblage between the two major seasons of the Omi River (Table 5). Total individual abundance reached its highest cumulative total during the dry season and dropped to its lowest overall level during the wet season. Total generic richness was also highest in the dry season and declined to its lowest count during the wet season. Both community diversity and dominance metrics followed this identical pattern, with the Shannon–Wiener index and Simpson's diversity index peaking during the dry season and falling to their lowest index evaluations in the wet season. The partitioning of individuals among the taxa, measured by Pielou's evenness index, reached its maximum values during the dry season and dropped to its lowest level during the wet season. Similarly, overall structural habitat variety, derived via the Margalef richness index, peaked in the dry season and fell to its minimum level during the wet season. Family-level complexity reached its highest count during the dry season and fell to its lowest count in the wet season. Biotic monitoring indices mirrored these structural indicators; the Biological Monitoring Working Party score reached its peak during the dry season and fell to its lowest value in the wet season, while the Average Score Per Taxon remained completely uniform, showing identical levels across both seasons. Conversely, both the raw number of individual EPT organisms and the corresponding percentage of EPT

individuals reached their absolute maximum values during the wet season and dropped to their lowest levels during the dry season.

Table 5
Seasonal Diversity indices of Aquatic Insects in Omi River,
Iwajowa Local Government Area, Oyo State, Nigeria from
December 2024 to September 2025

Diversity index	Dry season	Wet season
Total abundance (N)	529	511
Taxa richness (S)	36	29
Shannon–Wiener Index (H')	2.670	2.460
Simpson's Diversity (1 - D)	0.901	0.841
Pielou's Evenness (J')	0.745	0.731
Margalef Richness Index (d)	5.581	4.490
N0. of Families	12	11
BMWP	77	73
ASPT	6.4	6.4
Individual EPT	1	71
% EPT	0.19	13.89

3.5 The Relationship between Physico-chemical Parameters and Aquatic Insects of Omi River

The Canonical Correspondence Analysis (CCA) outlines the structural partitioning of variance between the measured physico-chemical water parameters and the aquatic insect assemblages of the Omi River across the first four ordination axes (Table 6). The first two canonical axes account for the majority of the constrained inertia, capturing a substantial cumulative proportion (63.50%) of the total explained variation. This demonstrates that a two-dimensional ordination space is structurally robust enough to represent the primary gradient patterns of the dataset, with Axes 3 and 4 explaining minor remaining components of the variance. Crucially, the Monte Carlo permutation tests reveal that none of the canonical axes reach statistical significance at the conventional alpha level ($p > 0.05$ across all axes). This clearly indicates that the observed linear combinations of environmental variables do not exert a statistically structured, deterministic control over aquatic insect distribution across the spatial-temporal sampling grid. Consequently, the CCA triplot (Fig. 2) is utilized as an exploratory and descriptive tool to evaluate the directional trends and underlying relationships between specific insect taxa and environmental gradients.

Table 6
Eigenvalue and Percentage of Total Inertia for the first four Axes of Canonical Correspondence Analysis of Physico-chemical parameters of water and Aquatic Insects of the Omi River in Iwajowa Local Government Area, Oyo State Nigeria from December 2024 to September 2025

Axix	Eigenvalue	% of total inertia	Monte Carlo permutation test (p-value)
1	0.22096	33.09	0.706
2	0.20304	30.41	0.262
3	0.13692	20.51	0.163
4	0.10231	15.32	0.309

Discussion

The physico-chemical characteristics of the Omi River indicate that the river maintained relatively uniform environmental conditions across the five sampling stations throughout the study period. The absence of significant spatial variation in most measured parameters suggests that the river experiences limited localized physico-chemical disturbance and possesses a relatively stable hydrological regime. Such spatial uniformity is often associated with rivers that retain continuous flow, relatively intact riparian vegetation and minimal point-source pollution inputs. Similar observations have been reported for tropical rivers where catchment characteristics remain relatively homogeneous and anthropogenic activities are not concentrated at specific river reaches (Forio et al., 2021; Tampo et al., 2021).

Water temperature remained remarkably consistent among sampling stations, ranging from 27.10°C to 28.70°C. This narrow temperature range reflects the tropical climatic conditions of southwestern Nigeria and indicates that the river is buffered against extreme thermal fluctuations (Oso and Olutona, 2023). Water temperature is one of the most influential environmental variables affecting aquatic organisms because it regulates metabolic activity, oxygen solubility, growth, and reproductive processes. The relatively stable temperatures recorded in this study are considered favourable for tropical aquatic insect communities and likely contributed to the persistence of diverse macroinvertebrate assemblages (Jerves-Cobo et al., 2020; APHA, 2023).

The lack of significant spatial differences in river width, depth, flow velocity, and discharge further demonstrates that the sampled reaches share comparable hydromorphological characteristics (Okoye and Eyo, 2021). Hydrological stability plays a fundamental role in determining habitat availability, substrate stability, and resource distribution for aquatic organisms. Rivers with relatively stable hydraulic conditions generally support more persistent macroinvertebrate communities because benthic habitats experience less physical disturbance and greater habitat continuity (Masese et al., 2020). Although Station 4 recorded a slightly higher flow velocity than the other stations, the difference was insufficient to produce statistically distinguishable hydrological conditions across the river.

Turbidity values were also spatially uniform, suggesting that sediment inputs were relatively evenly distributed along the river. Elevated turbidity often reduces light penetration, limits primary productivity, and interferes with the feeding activities of visually oriented aquatic organisms. However, the moderate turbidity levels recorded in this study are typical of tropical rivers and do not appear sufficiently elevated to adversely affect aquatic insect communities (Forio et al., 2021). Comparable turbidity patterns have been reported for tropical African rivers where seasonal rainfall, rather than localized pollution, constitutes the principal source of suspended sediments (Tampo et

al., 2021). Dissolved oxygen (DO) concentrations remained consistently above 6.7 mg L^{-1} throughout the study area. Such concentrations are generally regarded as adequate for sustaining diverse freshwater macroinvertebrate communities because most pollution-sensitive aquatic insects require DO concentrations exceeding 5 mg L^{-1} for normal physiological functioning (WHO, 2022; USEPA, 2022). The uniformly high dissolved oxygen values therefore provide strong evidence that Omi River possesses favourable conditions for aquatic life. These findings are supported by the subsequent occurrence of pollution-sensitive Ephemeroptera and Plecoptera taxa within the river, reinforcing the close relationship between dissolved oxygen availability and biological integrity (Aina et al., 2022).

Hydrogen ion concentration (pH) remained close to neutrality at all sampling stations, ranging from slightly acidic to slightly alkaline conditions. Most freshwater aquatic insects thrive within a pH range of approximately 6.5–8.5 because extreme acidity or alkalinity can impair physiological processes and reduce species diversity. Although Station 4 exhibited a slightly higher pH than the remaining stations, the overall pH values remained within internationally accepted limits for freshwater ecosystems and drinking water sources (WHO, 2022). The near-neutral pH recorded throughout the river likely contributed to the maintenance of diverse aquatic insect assemblages. Electrical conductivity (EC) and total dissolved solids (TDS) exhibited no significant spatial differences, indicating relatively consistent ionic composition throughout the river. Conductivity reflects the concentration of dissolved ions derived from natural weathering processes and anthropogenic inputs. The relatively moderate conductivity values observed in this study suggest that mineralization remained low and that anthropogenic pollution from domestic or industrial sources was limited (Nkwoji, 2023). Similar conductivity ranges have been associated with freshwater ecosystems exhibiting relatively good ecological condition in tropical regions (Forio et al., 2021).

Among all measured variables, biochemical oxygen demand (BOD) was the only parameter exhibiting significant spatial variation. Station 5 recorded the highest BOD value, whereas Station 3 recorded the lowest. Although statistically significant, the BOD values remained below levels generally associated with serious organic pollution. Biochemical oxygen demand represents the amount of dissolved oxygen consumed during microbial decomposition of biodegradable organic matter. Consequently, the elevated BOD observed at Station 5 may indicate localized organic inputs arising from domestic activities, riparian vegetation decay, or diffuse agricultural runoff (Ibrahim and Suleiman, 2022). Nevertheless, because dissolved oxygen concentrations remained relatively high, the river appears to possess sufficient assimilative capacity to maintain ecological balance despite localized organic loading. This finding suggests that the observed increase in BOD reflects mild, localized enrichment rather than severe environmental degradation.

Nitrate and phosphate concentrations remained relatively low throughout the study area and did not differ significantly among stations. These nutrients are essential for aquatic primary productivity but become problematic when present in excessive concentrations because they stimulate eutrophication, algal blooms, and oxygen depletion. The nutrient concentrations recorded in Omi River indicate that nutrient enrichment was minimal during the study period. This observation agrees with the high dissolved oxygen concentrations and favourable biological indices, suggesting that nutrient loading has not yet reached ecologically harmful levels (Aina et al., 2022). Similarly, calcium, magnesium, and total hardness exhibited relatively stable spatial distributions. Water hardness reflects the combined concentrations of calcium and magnesium ions and influences numerous biological processes, including exoskeleton development in aquatic insects. Moderate hardness values, such as those recorded in this study, are generally considered beneficial for freshwater organisms because they improve buffering capacity and reduce physiological stress associated with soft water conditions (APHA, 2023). The absence of significant spatial differences further indicates that the geological characteristics influencing water chemistry remain relatively

consistent throughout the river catchment. Collectively, the physicochemical results indicate that Omi River maintained favourable environmental conditions during the study period.

Seasonal variation is one of the principal drivers of ecological processes in tropical freshwater ecosystems, particularly in regions characterized by distinct wet and dry seasons. The observed seasonal differences in several physicochemical parameters of Omi River demonstrate the strong influence of rainfall, catchment hydrology, and river discharge on water quality. Similar seasonal patterns have been widely reported in tropical rivers, where precipitation alters river morphology, sediment transport, and physicochemical conditions through increased runoff and hydrological connectivity (Jerves-Cobo et al., 2020; Tampo et al., 2021). Water temperature remained remarkably stable between the dry and wet seasons despite differences in rainfall and river discharge. This stability reflects the relatively small annual variation in ambient air temperature typical of humid tropical climates (Oso and Olutona, 2023). Water temperature exerts a fundamental influence on metabolic activity, dissolved oxygen solubility, and the life cycles of aquatic organisms. The absence of significant seasonal temperature differences suggests that thermal conditions remained suitable for aquatic insects throughout the study period. Similar observations have been reported for tropical streams in East and West Africa, where seasonal rainfall influences hydrology more strongly than water temperature (Masese et al., 2020).

Hydrogen ion concentration (pH) also exhibited minimal seasonal fluctuation, remaining close to neutrality throughout the study period. Neutral to slightly alkaline conditions favour nutrient availability, microbial activity, and the physiological performance of aquatic insects. Stable pH conditions further suggest that Omi River is well buffered against seasonal acidification and receives limited acidic or alkaline effluents. The recorded pH values are consistent with the acceptable ranges recommended for freshwater ecosystems and drinking water and indicate favourable chemical conditions for sustaining aquatic biodiversity (WHO, 2022). The significant increase in river width, depth, and discharge during the wet season reflects the direct influence of seasonal rainfall on river hydrology. Increased precipitation enlarges channel dimensions through higher water volumes and enhances surface runoff from the surrounding catchment (Ibrahim and Suleiman, 2022). Such hydrological expansion is characteristic of tropical rivers and plays a crucial role in regulating habitat availability, sediment transport, and nutrient cycling. However, increased discharge also intensifies hydraulic disturbance, which can alter benthic habitats and influence aquatic insect distribution through drift and substrate instability (Allan and Castillo, 2022).

Turbidity increased significantly during the wet season, reflecting greater sediment input from overland flow and bank erosion. Elevated turbidity during periods of intense rainfall is common in tropical catchments where exposed soils and agricultural lands contribute suspended particles to river channels (Edegbene et al., 2021). Increased suspended sediments reduce light penetration, modify primary productivity, and may interfere with the feeding efficiency of visually oriented predators and filter-feeding organisms. Nevertheless, because turbidity increases coincided with seasonal rainfall rather than elevated nutrient concentrations or biochemical oxygen demand, the observed changes are more likely attributable to natural hydrological processes than to anthropogenic pollution (Forio et al., 2021). Interestingly, dissolved oxygen concentrations were significantly higher during the wet season despite increased turbidity. This pattern may be explained by enhanced atmospheric reaeration resulting from increased flow turbulence and greater water movement during periods of high discharge. Turbulent flow facilitates oxygen diffusion into the water column, thereby compensating for any increased oxygen demand associated with suspended organic matter. Elevated dissolved oxygen concentrations during the wet season have similarly been reported in tropical rivers experiencing increased flow velocity and channel turbulence (Jerves-Cobo et al., 2020). From an ecological perspective, the maintenance of high dissolved oxygen throughout both seasons provides favourable conditions for sensitive aquatic insect taxa, including Ephemeroptera and Plecoptera (Aina et al., 2022).

Biochemical oxygen demand remained consistently low and did not differ significantly between seasons, indicating that seasonal runoff did not substantially increase biodegradable organic loading within Omi River. Rivers receiving large quantities of untreated domestic waste or industrial effluents typically exhibit elevated BOD during the wet season due to wash-off of organic materials from surrounding catchments (Nkwoji, 2023). The consistently low BOD values observed in this study therefore suggest limited organic pollution and an effective capacity of the river to assimilate naturally occurring organic matter. Electrical conductivity and total dissolved solids were significantly higher during the dry season. Reduced river discharge during periods of low rainfall often concentrates dissolved ions through evaporation and diminished dilution, leading to increased conductivity and TDS (Ibrahim and Suleiman, 2022). Conversely, the larger water volumes characteristic of the wet season dilute dissolved salts despite increased catchment runoff. This seasonal pattern has been widely documented in tropical freshwater ecosystems and is considered indicative of natural hydrological dilution rather than pollution (APHA, 2023; Allan and Castillo, 2022).

Nitrate and phosphate concentrations remained relatively low throughout the year and did not vary significantly between seasons. The absence of significant seasonal nutrient enrichment suggests that agricultural runoff and domestic inputs were insufficient to cause excessive nutrient accumulation within the river. Consequently, the risk of eutrophication appears minimal during the study period. This observation agrees with the consistently high dissolved oxygen concentrations and the biological evidence presented in this study, both of which indicate a relatively healthy freshwater ecosystem. Calcium exhibited significant seasonal variation, whereas magnesium and total hardness remained relatively constant. Seasonal fluctuations in calcium may result from changes in groundwater contribution, weathering processes, and dilution during periods of increased rainfall. However, because total hardness remained relatively stable, these variations are unlikely to have significant ecological consequences for aquatic organisms.

The aquatic insect assemblage recorded in Omi River indicates a biologically diverse freshwater ecosystem with a strong dominance of predatory and semi-aquatic taxa. The occurrence of 44 taxa and more than one thousand individuals demonstrates that the river supports a relatively rich macroinvertebrate community capable of sustaining multiple trophic interactions. Similar levels of aquatic insect diversity have been reported from tropical rivers with moderate habitat heterogeneity and relatively favourable water quality conditions (Forio et al., 2021; Tampo et al., 2021). The dominance of *Rhagovelia* sp. (24.04%) is ecologically significant. Species of *Rhagovelia* are surface-dwelling predators and scavengers that are highly adapted to flowing waters with moderate current velocity. Their widespread distribution across all sampling stations suggests that the river provided suitable surface tension habitats, adequate dissolved oxygen, and sufficient prey resources. Similar dominance of *Rhagovelia* has been reported in tropical African streams where habitat structure remains relatively intact and organic pollution is low (Masese et al., 2020). The high abundance of *Pseudagrion* spp. and *Orthetrum* sp. further supports the conclusion that Omi River possesses favourable ecological conditions. Odonates are generally associated with well-oxygenated waters, submerged vegetation, and stable breeding habitats (Omokunle and Adebayo, 2024). Their substantial representation in the river indicates that habitat complexity and water quality were sufficient to support sensitive larval stages. Studies from Ghana and Burkina Faso have similarly shown that odonate abundance tends to increase in river reaches with good dissolved oxygen conditions and relatively undisturbed riparian zones (Tampo et al., 2021).

The concentration of *Orectogyrus* spp. at Station 1 and *Hydrochara* sp. at Station 2 suggests localized habitat preferences. Gyrinid beetles such as *Orectogyrus* are often associated with open water surfaces and moderate flow conditions, whereas *Hydrochara* species frequently occur in areas with abundant aquatic vegetation and organic

detritus. These spatial patterns indicate that microhabitat differences among stations contributed to the observed variation in aquatic insect abundance despite the relatively uniform physicochemical conditions described earlier.

Particularly noteworthy is the occurrence of *Elassoneuria* sp. and *Neoperla* sp., which are generally regarded as pollution-sensitive taxa. *Elassoneuria* sp. alone contributed 49 individuals (4.71%), with a pronounced concentration at Station 3 (33 individuals). The presence of these taxa corresponds closely with the high dissolved oxygen concentrations (6.79–7.36 mg L⁻¹) and low biochemical oxygen demand values reported in this study, reinforcing the biological evidence that Omi River experiences relatively low levels of organic pollution (Aina et al., 2022). In contrast, pollution-tolerant taxa were poorly represented. *Chironomus* sp. occurred as a single individual (0.10%), indicating that conditions favourable for tolerant dipteran dominance were absent during the study period. Rivers subjected to substantial organic enrichment often exhibit large populations of chironomids because of their tolerance to reduced oxygen concentrations and elevated organic loads (Nkwoji, 2023). The scarcity of *Chironomus* in Omi River therefore corroborates the low BOD values and favourable BMWP scores observed later in the study.

The markedly lower total abundance recorded at Station 4 (115 individuals) compared with Station 1 (293 individuals) suggests some degree of localized environmental limitation. Because physicochemical parameters at Station 4 remained within acceptable ecological ranges, the reduced abundance is more likely attributable to habitat factors such as substrate composition, reduced riparian cover, lower habitat complexity, or human disturbance within the immediate catchment (Okoye and Eyo, 2021). This observation illustrates the importance of integrating habitat assessment with water quality monitoring when evaluating freshwater ecosystems. From a broader ecological perspective, the assemblage structure of Omi River is characteristic of a tropical river with relatively good ecological integrity. The coexistence of abundant predatory Hemiptera and Odonata, diverse aquatic beetles, and several pollution-sensitive taxa indicates a balanced aquatic community with active trophic interactions. Similar assemblage patterns have been documented in tropical rivers of East and West Africa where moderate anthropogenic influence has not substantially altered ecosystem functioning (Forio et al., 2021; Masese et al., 2020).

The spatial diversity indices reveal important differences in the structure and ecological condition of aquatic insect communities along Omi River. Although the five sampling stations occurred within the same river system, variations in abundance, richness, and biological quality indicate that local habitat characteristics influenced community organization. Station 1 recorded the highest abundance (293 individuals), yet it did not possess either the highest taxa richness or the highest Shannon diversity. This demonstrates that abundance alone is not necessarily an indicator of biodiversity. High abundance may result from numerical dominance by relatively few taxa, whereas diversity indices incorporate both the number of taxa present and the distribution of individuals among them. Consequently, ecological assessments based solely on abundance may overestimate ecosystem quality if species composition is not simultaneously considered (Allan and Castillo, 2022). Station 2 exhibited the highest taxa richness (33 taxa) and the greatest Margalef richness index (5.694), indicating that it supported the widest variety of aquatic insect taxa. High taxonomic richness generally reflects favourable habitat heterogeneity, increased availability of ecological niches, and relatively stable environmental conditions. Rivers with diverse substrate types, marginal vegetation, and moderate hydraulic variability frequently support greater macroinvertebrate richness because different taxa exploit different microhabitats (Masese et al., 2020). The relatively high richness observed at Station 2 therefore suggests that this section of Omi River provides a wider range of ecological habitats than the remaining stations.

Despite having fewer individuals than Stations 1 and 2, Station 3 recorded the highest Shannon diversity ($H' = 2.702$) and the highest BMWP score (110). This finding is ecologically important because it demonstrates that the

community at Station 3 was not only taxonomically diverse but also composed of taxa more evenly distributed in abundance and of higher biological quality. Shannon diversity increases when communities contain numerous taxa with relatively balanced abundances, while BMWP increases with the presence of pollution-sensitive families. The concurrence of high Shannon diversity and high BMWP strongly suggests that Station 3 represented the most ecologically balanced section of the river during the study period (Aina et al., 2022).

Station 4 consistently recorded the lowest abundance, lowest taxa richness, lowest Margalef richness index, lowest BMWP score, and lowest ASPT value. Collectively, these indicators suggest comparatively reduced ecological quality relative to the other stations. However, Station 4 also exhibited the highest Pielou's evenness ($H' = 0.808$). This apparent contrast indicates that although relatively few taxa occurred at Station 4, those taxa were represented by fairly similar numbers of individuals. High evenness does not necessarily indicate high biodiversity; rather, it describes the uniformity of abundance distribution among the taxa that are present. Consequently, the high evenness observed at Station 4 should be interpreted alongside its lower richness and BMWP scores, which indicate that the community was relatively simple despite its balanced abundance distribution. The consistently high Simpson diversity values (0.814–0.896) across all stations further demonstrate that no single taxon overwhelmingly dominated the aquatic insect assemblage. Such values are generally associated with biologically stable communities in which ecological resources are shared among multiple taxa rather than monopolized by a few opportunistic species. Similar Simpson diversity values have been reported from tropical rivers exhibiting moderate habitat complexity and relatively low anthropogenic disturbance (Forio et al., 2021).

The BMWP and ASPT results provide independent biological evidence supporting the physicochemical assessment presented earlier. BMWP evaluates water quality based on the pollution tolerance of aquatic insect families, while ASPT standardizes the BMWP score by the number of scoring taxa. The relatively high BMWP (106–110) and ASPT (> 6.0) values observed at Stations 1, 2, 3, and 5 indicate that these reaches supported substantial numbers of pollution-sensitive taxa and were therefore in good ecological condition (Oso and Olutona, 2023). Although Station 4 produced comparatively lower scores (BMWP = 74; ASPT = 6.17), its ASPT remained above 6, suggesting that the decline reflected reduced richness rather than severe organic pollution. The observed spatial patterns correspond well with the physicochemical characteristics. Dissolved oxygen concentrations remained relatively high, biochemical oxygen demand remained low, and nutrient concentrations showed little spatial variation. These environmental conditions are generally favourable for sustaining diverse aquatic insect assemblages and likely contributed to the high biological quality observed across most sampling stations. From a conservation perspective, the diversity indices collectively indicate that Omi River retains relatively good ecological integrity. Nevertheless, the comparatively lower biological quality observed at Station 4 suggests that localized habitat alteration or reduced habitat complexity may have influenced aquatic insect communities at this reach (Okoye and Eyo, 2021). Continued monitoring of this station would therefore be advisable to determine whether the observed pattern reflects natural habitat variability or emerging environmental disturbance.

The seasonal diversity patterns observed in Omi River demonstrate the strong influence of tropical hydrological cycles on aquatic insect assemblages. Although the total abundance differed by only 16 individuals between seasons (528 in the dry season versus 512 in the wet season), diversity-related indices consistently indicated greater ecological complexity during the dry season. This distinction highlights an important ecological principle: community diversity is determined not only by the number of individuals but also by the number of taxa present and their relative abundance (Allan and Castillo, 2022). The higher taxa richness recorded during the dry season (36 taxa) suggests that stable hydraulic conditions favoured the persistence of a wider range of aquatic insect taxa. During periods of reduced discharge, stream substrates experience less scouring, allowing insects occupying

stones, submerged vegetation, woody debris, and sediments to establish more stable populations (Omokunle and Adebayo, 2024). Conversely, increased rainfall during the wet season often produces stronger currents, substrate disturbance, and downstream drift, reducing the number of taxa able to persist within individual sampling reaches. Similar seasonal reductions in macroinvertebrate richness have been reported in tropical rivers across East and West Africa, where rainfall-induced habitat instability rather than pollution was identified as the principal driver of community change (Masese et al., 2020; Forio et al., 2021).

The Shannon–Wiener diversity index followed the same seasonal pattern, declining from 2.670 during the dry season to 2.460 during the wet season. This reduction indicates that seasonal flooding not only reduced taxonomic richness but also altered the relative abundance of taxa. Shannon diversity is particularly sensitive to both richness and evenness, and therefore reflects changes in community organization associated with hydrological disturbance. Nevertheless, both values remain within a range generally considered indicative of moderately diverse tropical freshwater communities. The higher Simpson diversity observed during the dry season similarly reflects lower dominance by individual taxa under more stable environmental conditions. In contrast, the slight decline during the wet season suggests that some taxa became relatively more abundant while others decreased, a pattern commonly associated with seasonal flow disturbances. Importantly, the Simpson values remained relatively high in both seasons, indicating that no single taxon overwhelmingly dominated the community despite seasonal hydrological variation.

Pielou's evenness exhibited only slight seasonal variation, demonstrating that the proportional distribution of individuals among taxa remained relatively stable throughout the study period. This finding suggests that seasonal rainfall influenced the presence or absence of some taxa more than it altered the balance among the taxa that persisted. Such stability in evenness is often observed in tropical rivers experiencing predictable seasonal flow regimes rather than severe anthropogenic disturbance. The seasonal pattern observed in Margalef's richness index further confirms that reductions in wet-season diversity were primarily attributable to lower taxonomic richness rather than reductions in abundance. Since Margalef's index is particularly sensitive to the relationship between species richness and sample size, its decline from 5.572 to 4.487 indicates that hydrological disturbances affected the number of taxa more than the total number of individuals collected.

The BMWP scores of 77 and 73 indicate that biological water quality remained generally favourable during both seasons. Although the slight decline during the wet season suggests reduced representation of pollution-sensitive families, the difference is relatively small and is more plausibly explained by seasonal displacement of sensitive taxa than by deterioration in water quality. Increased discharge during the rainy season frequently redistributes benthic macroinvertebrates through drift and substrate disturbance, temporarily reducing local abundance of sensitive taxa without indicating ecological degradation (Bonada et al., 2020). Particularly noteworthy is the ASPT result. Despite the reduction in BMWP during the wet season, ASPT remained constant at 6.40 in both seasons. This indicates that the average pollution sensitivity of the taxa present was maintained throughout the year. Ecologically, this is an important finding because ASPT is less influenced by sample size than BMWP and is often regarded as a more robust indicator of biological water quality (Tampo et al., 2021). The consistency of ASPT therefore suggests that seasonal hydrological variation altered community composition without fundamentally changing the ecological quality of Omi River. Taken together, the diversity indices indicate that seasonal rainfall primarily influenced community structure rather than ecological condition. The river retained relatively high diversity, favourable biological quality, and balanced community organization throughout the study period, demonstrating considerable ecological resilience to predictable seasonal hydrological fluctuations. These findings also correspond closely with the physicochemical results, where most water quality parameters remained within acceptable ecological limits

despite seasonal changes. The agreement between physicochemical stability and biological responses strengthens the conclusion that Omi River remains in generally good ecological condition and that observed seasonal differences largely reflect natural hydrological processes rather than anthropogenic degradation.

The Canonical Correspondence Analysis (CCA) showed that the distribution of aquatic insect assemblages was primarily influenced by hydromorphological variables, including discharge, depth, stream width, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), and turbidity. The longer vectors of these variables indicate that they contributed more strongly to explaining variations in species composition than nutrient variables such as nitrate and biochemical oxygen demand (BOD). This finding suggests that habitat characteristics and flow conditions were the dominant ecological drivers of aquatic insect assemblages within the study area. Similar observations have been reported in tropical freshwater ecosystems, where habitat heterogeneity, channel morphology, and hydrological characteristics were identified as the principal determinants of macroinvertebrate community structure rather than individual water chemistry variables (Eriksen et al., 2021; Edegbene et al., 2021).

The close association of *Adenophlebia* sp., *Orectogyrus* sp., *Hydrodipnaya* sp., *Amphiops* sp., and *Dineutus* sp. with the discharge and depth vectors indicates that these taxa are adapted to deeper and relatively fast-flowing habitats. Such environments provide stable substrates, improved oxygen exchange, and diverse microhabitats that favour the establishment of many aquatic insects. Similar relationships were observed by Edegbene et al. (2021), who reported that discharge, channel characteristics, and physicochemical conditions significantly influenced macroinvertebrate assemblages in Nigerian rivers using Canonical Correspondence Analysis. Likewise, Okoye et al. (2021) found that water depth was one of the major environmental variables controlling macroinvertebrate abundance in a tropical stream in southeastern Nigeria. These similarities indicate that hydrological stability is a key ecological requirement for sustaining aquatic insect diversity in tropical river systems.

The association of *Hydrocanthus* sp., *Elodes* sp., *Elatoneura* sp., and *Lestinogomphus* sp. with electrical conductivity, TDS, and phosphate suggests that these taxa are relatively tolerant of increasing dissolved ions and moderate nutrient enrichment. Electrical conductivity and TDS are widely recognized as indicators of dissolved mineral content and are influenced by catchment geology as well as anthropogenic activities such as agriculture and domestic runoff. A study by Edegbene et al. (2021) demonstrated that conductivity and other physicochemical variables were among the major environmental factors structuring macroinvertebrate communities along pollution gradients in southern Nigeria. Similarly, Nkwoji (2023) reported that changes in conductivity and other water quality variables significantly influenced benthic macroinvertebrate composition in Nigerian aquatic ecosystems. The agreement between the present findings and these studies confirms that increasing ionic concentration modifies aquatic insect community composition by favouring relatively tolerant taxa.

The orientation of *Aulonogyrus* sp., *Notonecta* sp., and *Hydrometra* sp. towards the dissolved oxygen vector further demonstrates the importance of oxygen availability in maintaining aquatic insect assemblages. Dissolved oxygen is essential for respiration, metabolism, and successful development of aquatic insects, and higher DO concentrations generally support greater taxonomic richness. Similar observations were reported by Oso et al. (2023) during the ecological assessment of the Ikogosi Warm Spring, where stations with higher dissolved oxygen supported greater macroinvertebrate richness and better ecological condition than oxygen-deficient stations. Likewise, Omokunle (2024) found that dissolved oxygen was one of the principal environmental variables associated with aquatic insect diversity in a tropical river of southwestern Nigeria. Conversely, the opposite orientation of dissolved oxygen relative to EC and TDS in the present study suggests that increasing mineralization may reduce habitat suitability for oxygen-demanding taxa, a relationship also reported in recent tropical freshwater studies. The strong influence of turbidity observed in the present study indicates that suspended sediments remain an important ecological stressor

affecting aquatic insect distribution. High turbidity reduces light penetration, limits primary productivity, alters benthic substrates, and decreases habitat suitability for many sensitive aquatic insects. Similar findings were reported by Edegbene et al. (2021), who observed that anthropogenic disturbance and associated sediment inputs altered macroinvertebrate assemblages along environmental gradients in southern Nigeria. Furthermore, Eriksen et al. (2021) concluded from a global review that sedimentation and habitat degradation are among the major stressors responsible for changes in riverine macroinvertebrate communities across developing countries. The clustering of many taxa around the ordination origin in the present study also suggests the coexistence of ecological generalists capable of tolerating a broad range of environmental conditions, whereas species located close to specific environmental vectors exhibited narrower ecological preferences.

The environmental and biological dynamics of the Omi River closely mirror observations from other relatively protected lotic ecosystems across West Africa, especially within Nigeria. The low spatial variability in water quality parameters matches the baseline observations of Edegbene et al. (2021) and Nkwoji (2023), which indicate that southern Nigerian rivers lacking heavy industrialization maintain high ecological integrity and stable water chemistry. The temperature range of 27.10°C to 28.70°C aligns with southwestern Nigerian lotic systems evaluated by Oso and Olutona (2023). Additionally, the elevated dry-season mineralization (EC and TDS) followed by wet-season dilution is a well-documented hydrological marker of tropical catchments (Ibrahim and Suleiman, 2022). From a biological perspective, the dominance of the predatory *Rhagovelia* sp. and various odonates is highly consistent with macroinvertebrate patterns recorded in southwestern Nigerian forest streams by Omokunle and Adebayo (2024), where intact forest canopies provide significant terrestrial prey inputs. The presence of the pollution-sensitive mayfly *Elassoneuria* sp. and the stonefly *Neoperla* sp. under high DO conditions ($> 6.7 \text{ mg L}^{-1}$) is strongly corroborated by Aina et al. (2022), who identified these families as key indicators of healthy forest streams in southwestern Nigeria.

The primary role of hydromorphology (depth, discharge) over nutrient gradients in structuring the macroinvertebrate community is supported by Okoye and Eyo (2021) for southeastern Nigerian rivers. Furthermore, the wet-season decline in taxonomic richness (from 36 to 28) while maintaining a stable ASPT of 6.40 aligns with the regional findings of Tampo et al. (2021) in West African rivers, confirming that seasonal flooding acts as a physical redistributor (via drift and scouring) rather than a chemical stressor.

Conclusion

The Omi River represents a highly functional, resilient tropical lotic ecosystem characterized by excellent dissolved oxygen levels, low organic enrichment and neutral pH. The water chemistry remains highly uniform across the river, with only localized, mild organic loading at Station 5 that is successfully processed by the river's self-purification capacity. Seasonal hydrology is the primary driver of physical and chemical variations, causing elevated turbidity and structural dilution during the wet season, and concentrated mineral ions during the dry season. The river supports a diverse, biologically complex aquatic insect community dominated by sensitive taxa (e.g., *Elassoneuria* and *Neoperla*), confirming its high biological integrity. Hydromorphological conditions are the primary drivers of community structure, while seasonal high flows act as a natural physical filter that temporarily redistributes communities without degrading water quality. Future research should focus on how different stream bed substrates interact with changing tropical rainfall patterns. This will provide critical insights into how microhabitat availability and insect communities will adapt to climate-induced shifts in hydrology.

Declarations

Declarations Ethics approval and consent to participate

Not applicable for this kind of research.

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

Note

Tot. Abu. Means Total Abundance and Rel. Abu. Means Relative Abundance.

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Author Contribution

S.O.A. performed the practical laboratory work, collected the field samples, analyzed the data and drafted the manuscript. R. O. S. identified the botanical species found at the study site while both B. O. A. supervised the project, read the manuscript and provided critical corrections. All authors have read and approved the final version of the manuscript.

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Availability of data and materials:

Data are available on reasonable request.

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Figures

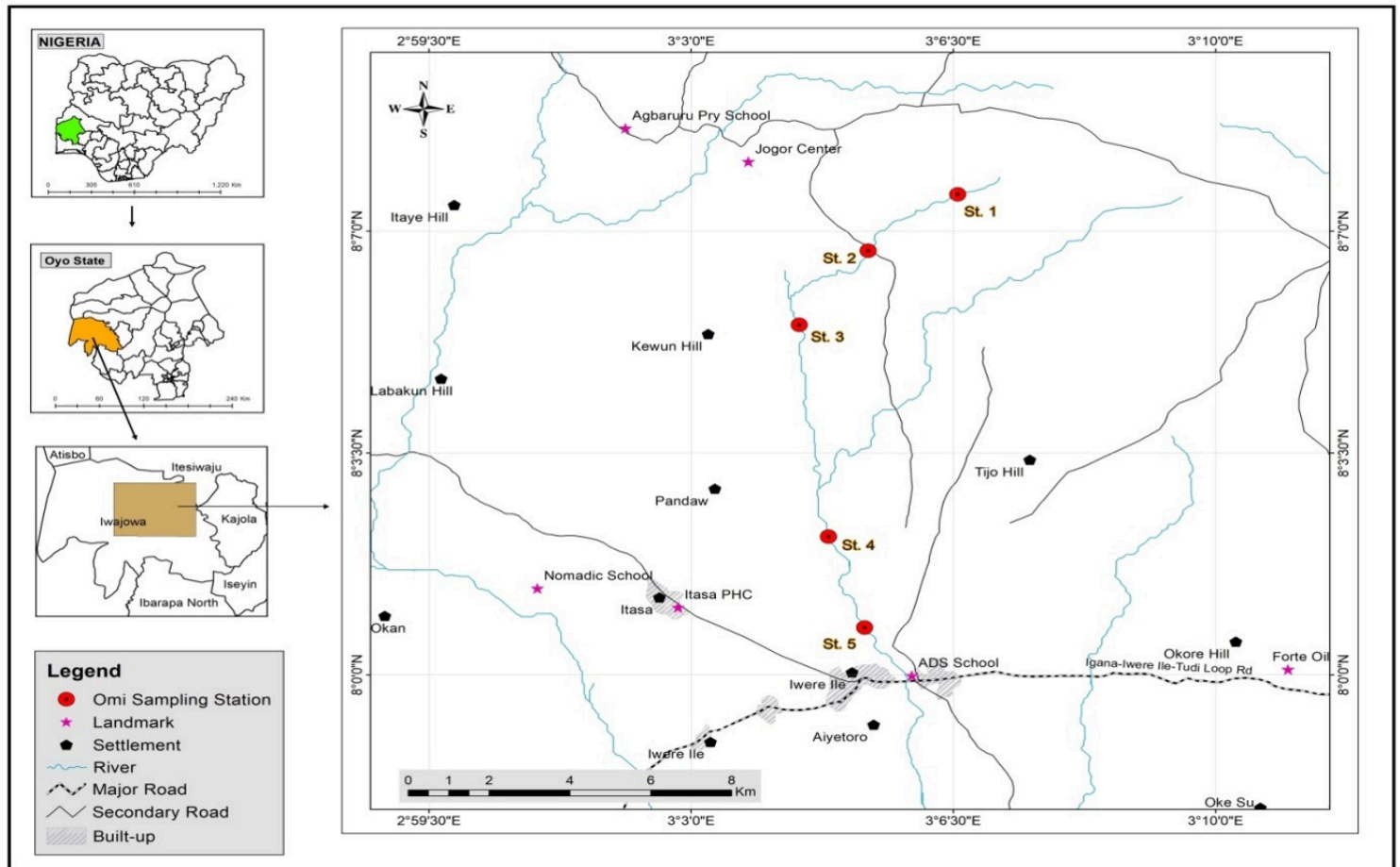


Figure 1

Map of the study area showing the selected sampling points on the Omi River, Iwajowa Local Government Area, Oyo State, Nigeria.

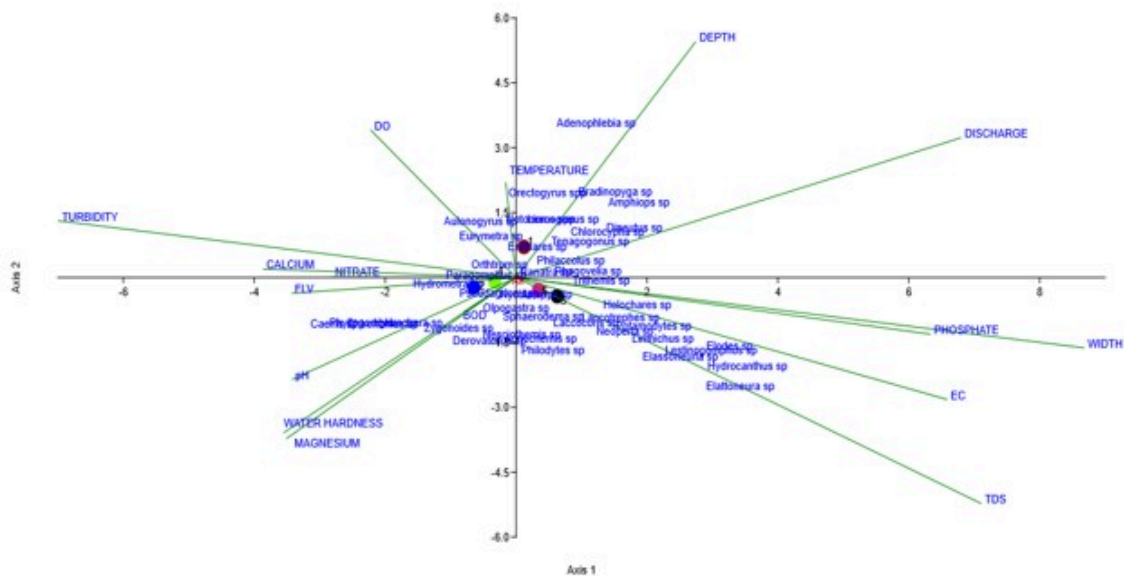


Figure 2

Canonical Correspondence Analysis (CCA) triplot showing the relationships between aquatic insect taxa and physico-chemical variables in the Omi River, Iwajowa Local Government Area, Oyo State Nigeria from December 2024 to September 2025.