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Research Article

Aquatic Insects as Biomonitoring Tools in Assessing Water Quality in a Tropical Freshwater Ecosystem

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Abstract

Background: Freshwater ecosystems, particularly in tropical regions, are increasingly threatened by anthropogenic activities that compromise water quality. Aquatic insects are widely used as tools for monitoring water quality in freshwater ecosystems. The ecological status of the Owena River, a tropical freshwater system in southwestern Nigeria, was assessed using aquatic insect communities, biotic indices, and physicochemical parameters.

Methods: Sampling was conducted across six stations along the river. Physicochemical parameters (including pH, temperature, dissolved oxygen, electrical conductivity, total dissolved solids, water depth, and flow rate) were measured in situ. Aquatic insects were collected using standardized sweep nets and identified to the family level. The Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Family Biotic Index (FBI), and Pollution Tolerance Index (PTI) were used to evaluate ecological health.

Results: A total of 2,920 aquatic insects belonging to six orders and 17 families were recorded. Odonata (32%) and Hemiptera (29%) dominated the assemblage. BMWP and ASPT values indicated moderate water quality, with slightly better conditions at the downstream stations. FBI values suggested fair water quality with some degree of organic pollution. The PTI results indicated that most insect families collected were moderately sensitive to pollution (73%).

Conclusion: The study demonstrates that aquatic insects and associated biotic indices are reliable, cost-effective tools for monitoring the ecological health of tropical freshwater ecosystems. These findings support their continued use in environmental assessment and water resource management strategies in developing regions.

Introduction

Freshwater ecosystems are among the most vulnerable environments on earth, facing increasing pressure from agricultural runoff, industrial effluents, urbanization, and deforestation [1]. These stressors degrade water quality, leading to biodiversity loss, disruption of ecosystem functions, and risks to human well-being [2]. Assessing and maintaining the ecological health of freshwater bodies is therefore essential for their conservation and for ensuring the sustainable use of water resources, particularly in tropical regions where population growth and land-use change are accelerating [3].

Conventional water quality assessment has relied heavily on physicochemical parameters, which provide only a snapshot of environmental conditions at the time of sampling [4]. While valuable, such approaches are limited in capturing cumulative and long-term ecological impacts of pollution [5]. To complement these methods, biological monitoring has gained prominence, as it integrates ecological responses of organisms to environmental stressors over time and provides a more comprehensive evaluation of ecosystem health [6].

Aquatic insects, in particular, are widely recognized as effective bioindicators of water quality due to their differential tolerance to pollution, sedentary habits, and occupation of diverse ecological niches [7,8]. Their community structure can therefore reflect the degree of disturbance and overall ecological status of rivers and streams.

To translate such biological data into measurable indicators of ecological condition, researchers often apply biotic indices, which are quantitative tools that link the presence or absence of specific taxa to varying levels of environmental stress [9]. Although widely used indices such as the BMWP, ASPT, FBI, and PTI were originally developed in temperate regions, their application in tropical systems requires caution and, ideally, regional adaptation to reflect local taxa and ecological contexts [10]. This highlights the need for localized biomonitoring frameworks that combine international approaches with indigenous ecological data.

In Nigeria, as in many developing nations, biomonitoring using aquatic insects remains underutilized despite the rich but vulnerable freshwater ecosystems and the growing pressures of development [6,11]. Establishing regionally adapted monitoring systems is therefore crucial to provide reliable ecological assessments that support conservation and sustainable management of water resources.

The present study aimed to assess the ecological status of the Owena River, a tropical freshwater system in southwestern Nigeria, by integrating aquatic insect communities, biotic indices, and physicochemical parameters.

Materials and methods

Study area

This study was conducted in the Owena River, located in the Ondo East Local Government Area of Ondo State, in the southwestern region of Nigeria (Figure 1). Sampling stations were selected along the Owena River to represent varying levels of anthropogenic influence. The selection ensured coverage of different land-use types and disturbance gradients, which provided a basis for comparative assessment of ecological status. Ondo State is situated within the tropical rainforest zone and shares boundaries with Ekiti State to the north, Kogi State to the northeast, Edo State to the east, Delta State to the southeast, Osun State to the northwest, and Ogun State to the southwest. The state lies between latitudes 5°45'N and 7°52'N and longitudes 4°20'E and 6°05'E, encompassing diverse ecological zones, including lowland rainforest, derived savanna, and riparian habitats.

Owena River plays a critical role in providing water for domestic use, agriculture, and small-scale industry to the surrounding communities. The river cuts through both rural and semi-urban settlements. The River is subject to various anthropogenic pressures, including farming activities, deforestation, and domestic waste discharge, which adversely affect its ecological health and the water quality of the ecosystem.

The region experiences a tropical climate, characterized by distinct wet and dry seasons. Temperatures are generally high throughout the year, with a mean annual temperature of about 26 °C to 29 °C and relative humidity levels often exceeding 70% during the wet season.

Sampling procedure

Sampling and identification of aquatic insects: Samples were collected monthly between the hours of 9:00 am to 2 pm, on sampling days from July 2024 to June 2025. Aquatic

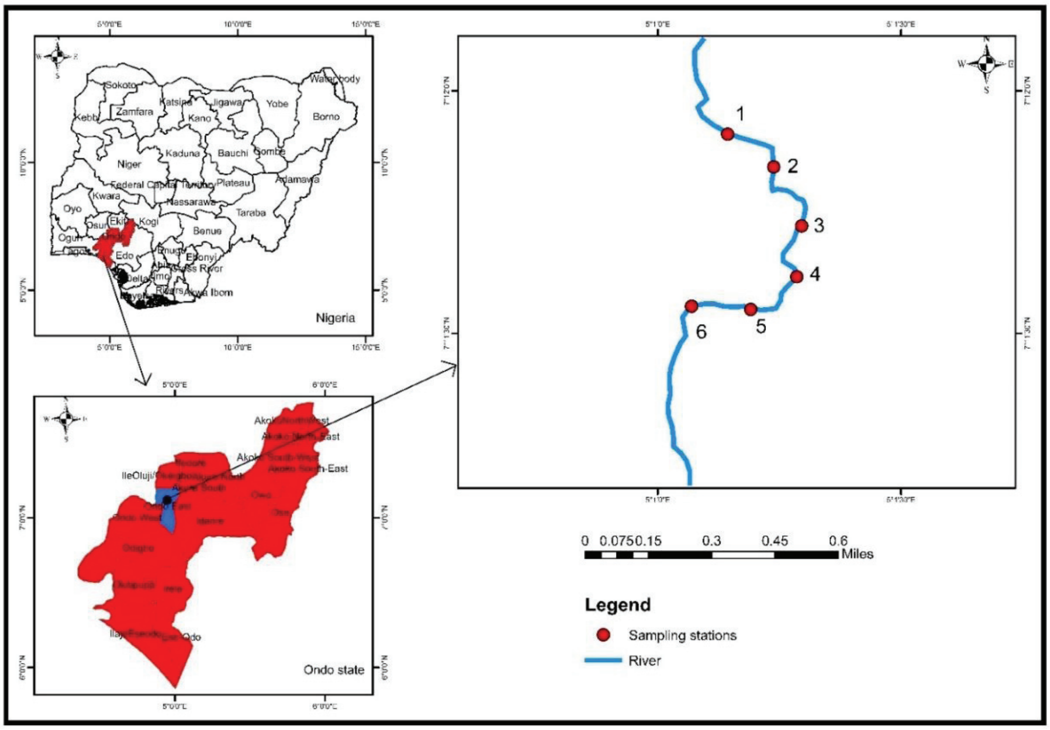

Figure 1: Study area map showing Nigeria, Ondo state, and the sampling stations in the Owena River.

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insects were sampled at the sampling stations with the usage of a dip-net of 200mm diameter. At each station, samples were taken for approximately 15-25 minutes, covering all major biotopes such as sand, gravel, silt, leaf litter, and submerged vegetation, to avoid bias toward any single microhabitat. The items harvested were placed in a sorting bucket, and the net was well-examined to check for organisms attached to the mesh. Other macroinvertebrate groups, such as mollusks (snails), crustaceans (crabs), and annelids (worms) that were encountered during sampling, were carefully returned to the river, as they were not the focus of the study. Caught insects were stored in 70% ethanol in specimen bottles labelled with respect to the sampling stations, description, and date of collection. The insects collected were examined with the aid of a hand lens and dissecting microscope at the Entomology laboratory, Department of Biology, Federal University of Technology, Akure, for proper identification. The viewed specimens were compared to standard taxonomic keys for aquatic insects [12-15].

Water sampling and analysis (Physico-chemical parameters): A total of seven (7) physicochemical parameters (pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), water depth (WD), and water flow rate (WFR) were measured. The pH, electrical conductivity, total dissolved solids, and temperature of the various sampling stations were measured using a HANNA portable meter (H19812-51). The dissolved oxygen level of the various water samples was measured using a HANNA dissolved oxygen meter. The water depth of the various streams was determined using a calibrated stick. Water flow rate was determined at each sampled point by placing a floating object (table tennis ball) on the water, and the time it took to travel a 5m distance was recorded using a stopwatch.

Biotic indices

Aquatic insect families identified in this study were assessed using four biotic indices: The Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Family Biotic Index (FBI), and the Pollution Tolerance Index (PTI). The tolerance scores used for each family are presented in Table 1. The BMWP–ASPT scoring system was based on Armitage, et al. [16], the FBI on Hilsenhoff [17], and the PTI on Ghosh and Biswas [18]. Although these indices were originally developed in temperate regions, they have been widely applied in tropical aquatic studies. In the present study, they were cautiously adopted and interpreted in relation to local ecological conditions, recognizing potential limitations due to regional differences in taxa and tolerance levels.

Biological Monitoring Working Party (BMWP): BMWP is a qualitative index that was initially designed in the United Kingdom to measure the water quality in relation to the macroinvertebrate families, especially the aquatic insects. The sensitivity to organic pollution is designated to each family with a score between 1 to 10; the higher the score, the greater its sensitivity. Calculation of the BMWP score involves adding the scores of each family of macroinvertebrates present in a sampling site, no matter how many are present. The higher the BMWP score, the more likely it is that there is better water quality and fewer pollutants. The interpretation for the BMWP score, adapted from Ganguly, et al. [19] and Sarikar and Vijaykumar [10], is presented in Table 2.

Average Score Per Taxon (ASPT): The **ASPT** is a refinement of the BMWP score that accounts for the number of taxa present. It is calculated by dividing the total BMWP score by the number of scoring taxa (families). This index provides a mean tolerance value and is useful for comparing water quality between sites with different levels of taxonomic richness. ASPT values range from 1 (highly polluted) to 10 (unpolluted). The interpretation for the ASPT score, adapted from Ganguly, et al. and Sarikar and Vijaykumar [10,19](Table 2).

Family Biotic Index (FBI): The Family Biotic Index is an index invented by Hilsenhoff [17], which is based on the abundance and tolerance values of macroinvertebrate families

Table 1: The tolerance score of each family to calculate the various biotic indices.

Order	Families	BMWP- ASPT	FBI	PTI
Coleoptera	Dytiscidae	5	5	Moderately sensitive to pollution
	Elmidae	5	4	Moderately sensitive to pollution
	Hydrophilidae	5	5	Moderately sensitive to pollution
	Gyrinidae	5	4	Moderately sensitive to pollution
Diptera	Chironomidae	2	9	Insensitive to pollution
Ephemeroptera	Baetidae	6	4	Sensitive to pollution
	Caenidae	7	2	Sensitive to pollution
	Leptophlebiidae	10	2	Sensitive to pollution
Hemiptera	Gerridae	5	0	Moderately sensitive to pollution
	Vellidae	5	5	Moderately Sensitive to pollution
	Corixidae	5	8	Moderately sensitive to pollution
	Notonectidae	5	0	Moderately sensitive to pollution
Odonata	Libellulidae	8	2	Moderately sensitive to pollution
	Coenagrionidae	6	8	Moderately sensitive to pollution
	Gomphidae	8	4	Moderately sensitive to pollution
	Aeshnidae	8	3	Moderately sensitive to pollution
Plecoptera	Perlidae	10	1	Sensitive to pollution

Table 2: Interpretation for BWMP and ASPT score.

BWMP Score	ASPT Score	Water Quality category
>120	>5.4	Excellent quality
101-120	4.81 – 5.4	Good quality
61-100	4.31 – 4.8	Regular quality
36-60	3.61 – 4.3	Contaminated
16-35	3.0 – 3.6	Very contaminated
<15	<3.0	Extremely contaminated

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to measure the extent of the organic pollution in an aquatic environment. Every family receives a numerical tolerance value (0 to 10), which is low when susceptible to organic pollution and high when tolerant to organic pollution. The weighted average of the above tolerance values gives the FBI, with the relative abundance of each taxon. The lower the FBI scores recorded, the better the water quality, whereas higher values indicate organic pollution and worsening of the ecological situation. Table 3 shows the interpretation for various FBI score ranges.

Family Biotic Index was calculated using.

$$FBI = \frac{\sum (ni \times ti)}{N}$$

Where ni = Number of individuals in each family, ti = The tolerance level of each family, and N = Total number of individuals in the sample.

Pollution Tolerance Index (PTI): The Pollution Tolerance Index (PTI) is a simple scoring system that categorizes macroinvertebrates based on their known tolerance or intolerance to pollution. Taxa are classified into sensitive, moderately sensitive, and insensitive to pollution. The group with the highest percentage can be used to determine the quality of the water. The PTI provides a rapid and easy-to-interpret assessment of environmental stress.

Data analysis

The data collected from the study stations were compiled and analysed statistically using inferential and descriptive statistics. The data on physicochemical parameters were subjected to one-way analysis of variance (ANOVA) ($p < 0.05$), and where significant differences existed, means were separated using Tukey's test. ANOVA was done using SPSS 21.0 software package. Correlation analysis was used to show the relationship between the aquatic insects and physicochemical parameters obtained in the river. Microsoft Excel was used to compute and calculate the relative abundance of insects. Also, Excel was used to calculate the biotic indices.

Results

Physicochemical parameters of the owena river

The physicochemical characteristics of the Owena River across six sampling stations are presented in Table 4. The pH ranged from 7.78 at Station 6 to 7.94 at Station 1. The water was generally slightly alkaline across all sites. Station 1 recorded a significantly higher pH compared to some other stations. Temperature remained relatively consistent, ranging from 26.81 °C at Station 1 to 27.15 °C at Station 3. No significant differences were observed among the stations. Electrical conductivity (EC) values varied slightly, from 125.15 mg/L at Station 5 to 131.82 mg/L at Station 4. However, the differences were not statistically significant, indicating relatively uniform ionic concentrations across the river. Total dissolved solids (TDS) showed some spatial variation, with values increasing from 59.70 mg/L at Station 1 to 66.36 mg/L at Station 6. This increase was statistically significant. Dissolved oxygen (DO) levels were generally high, ranging between 6.49 mg/L (Station 5) and 7.29 mg/L (Station 3). The differences across stations were not significant. There was significant variation in water depth (WD) across stations. Deeper conditions were recorded at Stations 1 and 2 (0.32 m and 0.36 m, respectively), while Stations 3 to 6 had shallower depths ranging from 0.22 m to 0.24 m. Water flow rate (WFR) also differed among stations. The highest flow was observed at Stations 1 and 3 (0.40 m/s), while the lowest values were recorded at Stations 5 and 6 (0.31 m/s).

Table 3: Standard for water quality using Hilsenoff's family biotic index [17].

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00 – 3.75	Excellent	Organic pollution unlikely
3.76 – 4.25	Very good	Possible slight organic pollution
4.26 – 5.00	Good	Some organic pollution is probable
5.01 – 5.75	Fair	Fairly substantial pollution is likely
5.76 – 6.50	Fairly poor	Substantial pollution likely
6.51 – 7.25	Poor	Very substantial pollution is likely
7.26 – 10.00	Very poor	Severe organic pollution is likely

Composition, distribution, and abundance of aquatic insects in the owena river

A total of 2,920 aquatic insect specimens, comprising 6 orders and 17 families, were recorded across the six sampling stations in the Owena River (Table 5). The insect orders present include Coleoptera, Diptera, Ephemeroptera, Hemiptera, Odonata, and Plecoptera. The percentage composition of aquatic insect orders in the river is presented in Figure 2. Within the order Coleoptera, four families were recorded: Dytiscidae, Elmidae, Hydrophilidae, and Gyrinidae, with a combined total of 355 individuals, accounting for 12.16% of the total insect population.

The order Diptera was represented by Chironomidae, with 363 individuals, comprising 12.43% of the total collection. Ephemeroptera was represented by three families: Baetidae, Caenidae, and Leptophlebiidae, contributing a total of 356 individuals or 12.19% of the overall abundance. In the order Hemiptera, five families (Gerridae, Veliidae, Corixidae, and Notonectidae) were identified. These accounted for 842 individuals, representing 28.84% of the total insect population.

The order Odonata comprises four families: Libellulidae, Coenagrionidae, Gomphidae, and Aeshnidae. Odonata contributed 884 individuals, making up 30.28% of the total assemblage. Plecoptera was represented by Perlidae, which occurred at four stations (3 to 6), with a total of 66 individuals, comprising 2.26% of the total collection. The number of individuals per station ranged from 402 (Station 2) to 566 (Station 3). The composition and distribution of aquatic insect taxa varied across stations, indicating spatial differences in community structure along the river.

Relationship between aquatic insect families and physicochemical parameters

The relationship between aquatic insect families and physicochemical parameters in the Owena River is presented in

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Table 4: Mean and Standard Error of the physicochemical parameters in the Owena River.

PARAMETERS	STATION					
	1	2	3	4	5	6
pH	7.94±0.04^{b}	7.82±0.04^{ab}	7.82±0.04^{ab}	7.86±0.02^{ab}	7.83±0.03^{ab}	7.78±0.02^{ab}
Temp (°C)	26.81±0.20^{a}	27.04±0.23^{a}	27.15±0.27^{a}	26.95±0.22^{a}	27.06±0.23^{a}	27.01±0.21^{a}
EC (mg/L)	126.97±2.24^{a}	126.67±1.72^{a}	127.58±2.38^{a}	131.82±1.97^{a}	125.15±2.31^{a}	128.48±2.54^{a}
TDS (mg/L)	59.70±1.41^{a}	62.73±1.59^{ab}	63.94±1.44^{ab}	64.55±1.45^{ab}	64.85±1.24^{ab}	66.36±1.68^{b}
DO (mg/L)	6.87±0.41^{a}	6.88±0.39^{a}	7.29±0.50^{a}	6.96±0.46^{a}	6.49±0.37^{a}	6.65±0.38^{a}
WD (m)	0.32±0.02^{b}	0.36±0.02^{b}	0.24±0.02^{a}	0.22±0.02^{a}	0.23±0.02^{a}	0.22±0.02^{a}
WFR (m/s)	0.40±0.02^{bc}	0.37±0.01^{abc}	0.40±0.02^{bc}	0.32±0.02^{ab}	0.31±0.02^{a}	0.31±0.02^{a}

Mean followed by similar alphabets across the row indicates no significant difference ($p > 0.05$) using Tukey's post hoc test.

Table 5: Composition, distribution, and abundance of insects in the Owena River.

ORDER	COMMON NAME	STATION						TOTAL	%
		1	2	3	4	5	6		
COLEOPTERA									
Dytiscidae	Predaceous diving beetles	12	7	15	11	15	13	73	2.5
Elmidae	Riffle beetles	8	4	11	8	10	10	51	1.75
Hydrophilidae	Water scavenger beetles	3	7	14	5	6	13	48	1.64
Gyrinidae	Whirligig beetles	33	35	33	32	23	27	183	6.27
DIPTERA									
Chironomidae	Non-biting midges	39	50	73	70	63	68	363	12.43
EPHEMEROPTERA									
Baetidae	Small minnow mayflies	22	3	42	28	34	24	153	5.24
Caenidae	Small square gill mayflies	4	2	30	33	25	19	113	3.87
Leptophlebiidae	Prong-gilled mayflies	6	2	16	22	24	20	90	3.08
HEMIPTERA									
Gerridae	Water striders	87	91	69	84	73	70	474	16.23
Veliidae	Riffle bugs	45	41	49	55	50	45	285	9.76
Corixidae	Water boatmen	5	6	7	14	11	6	49	1.68
Notonectidae	Backswimmers	6	5	5	6	6	6	34	1.16
ODONATA									
Libellulidae	Skimmer dragonflies	95	77	101	99	83	70	525	17.98
Coenagrionidae	Narrow-winged damselflies	50	57	58	53	41	40	299	10.24
Gomphidae	Clubtail dragonflies	17	10	10	17	4	6	64	2.19
Aeshnidae	Darners dragonflies	11	5	13	10	6	5	50	1.71
PLECOPTERA									
Perlidae	Common stoneflies	0	0	20	18	16	12	66	2.26
TOTAL		443	402	566	565	490	454	2920	100

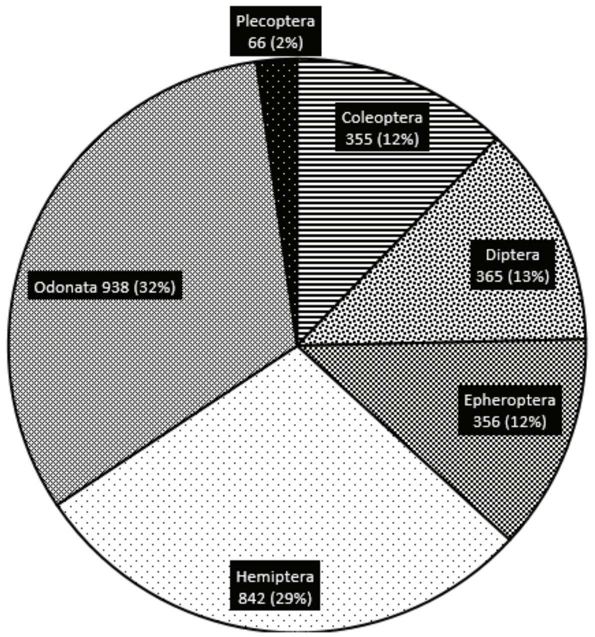

Figure 2: Percentage composition of aquatic insect orders collected from Owena river.

Table 6. Hydrophilidae showed a strong negative relationship with total dissolved solids (-0.66), while Gyrinidae recorded a significant negative correlation with pH (-0.67). Perlidae displayed significant positive associations with dissolved oxygen (0.66), water depth (0.64), and water flow rate (0.70). These results indicate that only a few families exhibited statistically significant relationships with specific parameters, while others showed non-significant or weak correlations.

Biotic indices

The Biotic Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), and Family Biotic Index (FBI) results are presented in Table 7. The BMWP scores were consistent across Stations 1 and 2 (87), while Stations 3 to 6 recorded higher and uniform values of 97. The overall BMWP score was 97. For the ASPT, Stations 1 and 2 had identical values of 5.44. Stations 3, 4, and 5 had a slightly higher and equal value of 5.71. Station 6 recorded the highest ASPT value at 6.47, which also represented the overall ASPT value. The FBI values ranged from 5.40 to 5.98. Station 2 had the highest FBI value (5.98),

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Table 6: The relationship between aquatic insects' families and physicochemical parameters in the Owena River.

Families	pH	Temp	DO	EC	TDS	WD	WFR
Libellulidae	-0.42	-0.15	0.52	0.17	0.12	0.43	0.47
Coenagrionidae	-0.40	0.17	0.11	-0.19	-0.30	0.12	0.11
Gomphidae	-0.25	0.15	0.08	-0.07	-0.19	0.07	0.02
Aeshnidae	-0.20	0.25	-0.05	-0.05	-0.20	0.04	0.01
Baetidae	-0.11	0.24	0.21	-0.11	-0.33	0.05	0.01
Caenidae	-0.24	0.08	0.52	-0.03	-0.25	0.23	0.23
Leptophlebiidae	-0.38	0.03	0.28	-0.15	-0.31	0.23	0.26
Dytiscidae	-0.30	0.23	0.05	-0.08	-0.21	0.00	-0.02
Elmidae	-0.07	0.54	-0.15	-0.48	-0.58	-0.31	-0.26
Hydrophilidae	0.00	0.52	-0.48	-0.55	-0.66*	-0.42	-0.41
Gyrinidae	-0.67*	-0.23	0.43	0.25	0.08	0.52	0.51
Gerridae	-0.46	-0.13	0.36	0.24	0.06	0.42	0.39
Veliidae	-0.57	-0.25	0.44	0.34	0.15	0.53	0.50
Corixidae	-0.24	0.16	-0.09	-0.36	-0.45	0.02	0.00
Notonectidae	-0.48	0.11	0.18	-0.27	-0.35	0.13	0.21
Chironomidae	-0.16	-0.17	0.58	0.25	0.09	0.38	0.29
Perlidae	-0.55	-0.42	0.66*	0.25	0.15	0.64*	0.70*

KEY: Temp = Temperature; pH= Potential of Hydrogen; EC = Electric Conductivity; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; WD = Water Depth and WFR = Water Flowrate

Table 7: Biotic Indices (BMWP, ASPT, and FBI) results for the six stations at the Owena River.

Biotic indices	Station						Overall
	1	2	3	4	5	6	
BMWP	87	87	97	97	97	97	97
ASPT	5.44	5.44	5.71	5.71	5.71	6.47	6.47
FBI	5.64	5.98	5.44	5.42	5.4	5.52	5.55

followed by Station 1 (5.64). The lowest FBI value was observed at Station 5 (5.40). The overall FBI value across all stations was 5.55.

The pollution tolerance index for the Owena River is presented in Table 8. A total of 422 individuals, representing 14.45% of the total insect population, belonged to families that are sensitive to pollution. These included Baetidae (5.24%), Caenidae (3.87%), Leptophlebiidae (3.08%), and Perlidae (2.26%). Moderately sensitive insect families accounted for the highest proportion of individuals, with a total of 2,135 insects representing 73.11% of the population. Families in this category included Dytiscidae (2.50%), Elmidae (1.75%), Hydrophilidae (1.64%), Gyrinidae (6.27%), Gerridae (16.23%), Corixidae (1.68%), Notonectidae (1.16%), Libellulidae (17.98%), Coenagrionidae (10.24%), Gomphidae (2.19%), Aeshnidae (1.71%), and Vellidae (9.76%). The pollution-insensitive group was represented solely by Chironomidae, with 363 individuals comprising 12.43% of the total abundance.

Discussion

The findings from the Owena River reveal an ecosystem that still supports diverse aquatic insect communities but is experiencing moderate ecological stress. The presence of sensitive taxa such as Ephemeroptera and Plecoptera alongside tolerant groups like Chironomidae reflects a transitional ecological condition where sections of the river retain good water quality, while others show signs of localized disturbance. This mosaic pattern of community structure has also been reported in other tropical rivers where human influence is unevenly distributed [20,21].

Table 8: Pollution tolerance index result for the Owena River.

Group	Insect families	Number of insects	Abundance
Sensitive to Pollution	Baetidae	153	5.24
	Caenidae	113	3.87
	Leptophlebiidae	90	3.08
	Perlidae	66	2.26
	Total	422	14.45
Moderately sensitive to pollution	Dytiscidae	73	2.5
	Elmidae	51	1.75
	Hydrophilidae	48	1.64
	Gyrinidae	183	6.27
	Gerridae	474	16.23
	Corixidae	49	1.68
	Notonectidae	34	1.16
	Libellulidae	525	17.98
	Coenagrionidae	299	10.24
	Gomphidae	64	2.19
	Aeshnidae	50	1.71
	Vellidae	285	9.76
	Total	2135	73.11
Insensitive to pollution	Chironomidae	363	12.43
	Total	363	12.43

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The biotic indices applied in this study reinforce this interpretation. While BMWP and ASPT indicated good to excellent water quality in some stations, the FBI suggested moderate organic enrichment. Such discrepancies highlight the importance of using multiple indices to capture the complexity of tropical rivers, as reliance on a single metric may obscure localized stressors. The improvement in water quality indices downstream could be attributed to self-purification processes and greater habitat heterogeneity, emphasizing the resilience of tropical river systems when natural conditions are preserved [10].

The dominance of moderately tolerant families such as Gerridae, Libellulidae, and Coenagrionidae suggests that the river is under sustained but non-critical stress, most likely from agricultural and domestic inputs. Their prevalence, alongside the occurrence of Chironomidae, underscores the influence of nutrient enrichment and organic matter on structuring insect communities. Similar patterns have been observed in Nigerian and South African rivers, where land-use change and effluents exert gradual pressure on aquatic ecosystems [22].

The significant correlations observed highlight the sensitivity of specific insect families to environmental conditions in the Owena River. The association of Perlidae with oxygen-rich and fast-flowing habitats confirms their role as indicators of good water quality, consistent with earlier studies in tropical freshwater [23]. In contrast, the negative relationship of Hydrophilidae with dissolved solids suggests vulnerability to organic or ionic pollution, while the response of Gyrinidae to pH reflects their preference for moderately acidic waters. These patterns emphasize the ecological importance of aquatic insects as bioindicators and provide insight into how physicochemical variables shape community distribution in freshwater ecosystems.

From a management perspective, these findings highlight the vulnerability of the Owena River to escalating anthropogenic pressure. Although ecological health is not severely compromised, the decline in abundance of highly sensitive groups such as Perlidae and Baetidae suggests that further degradation could lead to significant biodiversity loss. Protecting riparian zones, regulating agricultural runoff, and monitoring organic pollution sources are therefore critical to sustaining the ecological functions of the river.

Overall, the study demonstrates the value of integrating biotic indices with physicochemical data for assessing tropical river health. The results provide a baseline for long-term monitoring of the Owena River and contribute to the growing body of evidence that locally adapted biomonitoring approaches are necessary for tropical freshwater ecosystems [24-29].

Conclusion

The ecological condition of the Owena River has been classified as a moderately impaired tropical freshwater system with ecosystem resilience, but also evidence of anthropogenic pressure. The characteristics of the physicochemical parameters, i.e., pH, temperature, electrical conductivity, and dissolved oxygen, were in appropriate ranges that supported aquatic organisms in the specific river conditions of the tropics. Nevertheless, the spatial patterns of total dissolved solids have indicated local inflows of agricultural or domestic material. These conditions were mirrored by aquatic insect assemblages with a combination of pollution-sensitive insects, such as Ephemeroptera and Plecoptera, surmounted by tolerant insects, such as Chironomidae. This richness denotes that the system harbours high habitat quality at certain places, and another portion is facing the effects of environmental stress. Biological indices yielded a detailed image. There were signs of very good water quality in downstream areas measured by the ASPT, average quality data by BMWP scores, and organic pollution data by FBI values. The fact that these different assessments have different results points to the complexity of river ecosystems and the significance of multiple indices to more effectively evaluate the ecology. In general, the Owena River is a transitional ecosystem, which still remains effective in sustaining and maintaining diverse macroinvertebrate life, although increased anthropogenic pressure puts stress on it. Close observation and careful management practices to ensure its continued ecological soundness are definitely needed to curb its degradation.

Author contributions

MOA conceived and led the research and contributed to the writing of the manuscript. BWA and JAA provided supervision, critically reviewed, and edited the manuscript. ROO contributed to manuscript writing and conducted fieldwork for data collection. KJF also participated in fieldwork and data collection.

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