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# Ecological Assessment of a Tropical River Using Aquatic Insects Assemblage and Water Quality as Indicators

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**ABSTRACT**

Ara River is the largest waterbody in Ara, Southwestern Nigeria. The ecological status of the river was investigated using aquatic insect assemblage and some environmental variables as indicators. This was done to determine the suitability of the river to carry out the important ecological and axillary functions that it performs. Aquatic insects were sampled once monthly from January – June 2021 using long handle D frame net (500 µm mesh) and hand-picking methods where appropriate. Environmental variables such as air and water temperature, water depth, flow rate, Dissolved Oxygen (DO), and Conductivity were also investigated using appropriate standard procedures. A total of 344 aquatic insects which comprised 13 genera, 10 families, and 6 orders were collected in Ara River during the study. Odonata was the dominant order while *Libellula* sp. was the dominant taxa. Values obtained for DO were relatively low while Conductivity was high. The equitability index indicated that the collected taxa were well distributed in the sampling points. Canonical correspondence analysis revealed that many of the recorded taxa were closely associated with low values of DO and high flow rates. The dominance of pollution-tolerant species, low DO, and high conductivity indicate that Ara was slightly polluted at the time this study was carried out. Efforts should be made to address the source of pollutants in the water body to preserve the biodiversity there-in and ensure that the river can sustain the important functions that it performs.

**Keywords:** Aquatic insects, Environmental variables, Distribution, Ecology, Pollution.

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## INTRODUCTION

Aquatic insects have constituted the most diverse and important component of the biota in the freshwater ecosystem. These organisms are important elements in the ecological dynamics of both lentic and lotic environments [1]. Aquatic insects equally play a vital role in the cycle of materials as well as in the energy flow in the aquatic environment [2]. A very good number of insects are good indicators of environmental quality and this is a result of the fact that they have a wide range of sensitivity to environmental contamination [3]. For instance, members of the Ephemeroptera, Plecoptera, and Tricoptera (EPT) have been known to be the most sensitive to pollution and natural and anthropogenic influences in the environment. As such, they are considered an important component of community assemblages of aquatic insects [4]. Apart from these, the distribution, composition, diversity, high rate of reproduction, short time generation, and rapid ways of colonizing freshwater habitats by aquatic insects have made them useful as bio-indicators of the integrity of freshwater ecosystem [5]. Therefore, understanding the species composition and distribution in communities is crucial in the determination of the ecological status of water bodies [6].

The occurrence and distribution of aquatic insects are mainly regulated by factors such as Elevation, Flow velocity, Vegetation, and Physico-chemical parameters of the waterbodies [7]. Changes in these environmental variables provide useful information in the bio-monitoring and assessment protocols [4]. Therefore, the community structure of aquatic insects gives an insight into the types of ecological processes that regulate such assemblages and populations. A fairly good number of studies in which aquatic insects have been used as bio-indicators are available. Some important studies in which aquatic insects have been used as bio-indicators of water quality in Nigeria include [8-10].

The freshwater ecosystem is very sensitive to changes in the environment. As such, the importance of regular and intensive monitoring of water quality cannot be overemphasized [11]. The freshwater ecosystem needs to be preserved and protected as it not only supports a great diversity of life forms but it is also important to humans and industries [12]. Therefore, monitoring is essential in knowing the current health status of freshwater ecosystems in an attempt to consistently ensure adequate water quality and quantity. Ara River is an important waterbody, especially to the inhabitants of Ara and its environs. The river, being the largest in Ara town provides potable water and serves other axillary functions such as provision of irrigation water and ground for fishing activities. However, despite the enormous importance of this waterbody to this community, no documented effort assessed the health status of the water to date. Hence, this study aims to assess the current health status of Ara River using the community structure of aquatic insects about some environmental variables.

## MATERIALS AND METHODS

*Study area*

The study was carried out on Ara River is located in Ara, Ejigbo Local Government Area, Southwestern Nigeria **(Figure 1)**. The river is named after the town (Ara) because it is the largest river in the town. Ara covers between Latitude 07° 92.8' N to 07° 93.2' N and Longitude of 04° 31.2' E to 04° 31.7' E. Ara falls within the lowland tropical rainforest vegetation zone of Nigeria [13] characterized by emergent trees with multiple canopies and lianas most of which had since given way to secondary forest and derived savannah [14]. The area is surrounded by patchy forest lands, scattered residential buildings, and some farmlands. Some of the crops grown around Ara include; annual and perennial crops such as; cassava, cocoa, oil palm, and citrus crops. Ara River is an important source of water for domestic and agricultural activities. For this study, four sampling locations were selected as sampling points designated as SP1, SP2, SP3, and SP4 on the course of the river. The points were located close to the littoral zone of the river since aquatic insects are predominantly found around this part of the waterbodies.

*Sampling procedures*

Aquatic insects were sampled once monthly from January to June 2021 using a long handle D-frame net (500 µm mesh). Hand-picking and direct search methods were also employed where necessary, especially around the shallow portions of the river. Sampling was usually carried out between 8 and 11 am. The collected insects were placed in a white tray for sorting and screening. The aquatic insects per sampling point were counted and preserved using 70% ethanol. Identification of the specimens was done to the possible lowest taxonomic level using standard taxonomic keys and guides such as Water Research Commission (WRC) guides to the freshwater invertebrates of Southern Africa [15] and a pictorial guide [16]. Environmental factors that influence the community assemblage of the aquatic insects at the study sites were investigated during the sampling period. Such environmental factors include pH, Air temperature (AT), water temperature (WT), water depth (WD), water velocity (WT), dissolved oxygen (DO), and conductivity (EC) [17]. The temperature was determined on-site with a Mercury-in-glass thermometer while a Hanna multi-probe meter (HANNA 9828) was used for measuring pH, dissolved oxygen, and electrical conductivity. The water current velocity of the stream was estimated by the displacement method in which a float, meter rule, and stopwatch were used over a distance of 10 m [18].

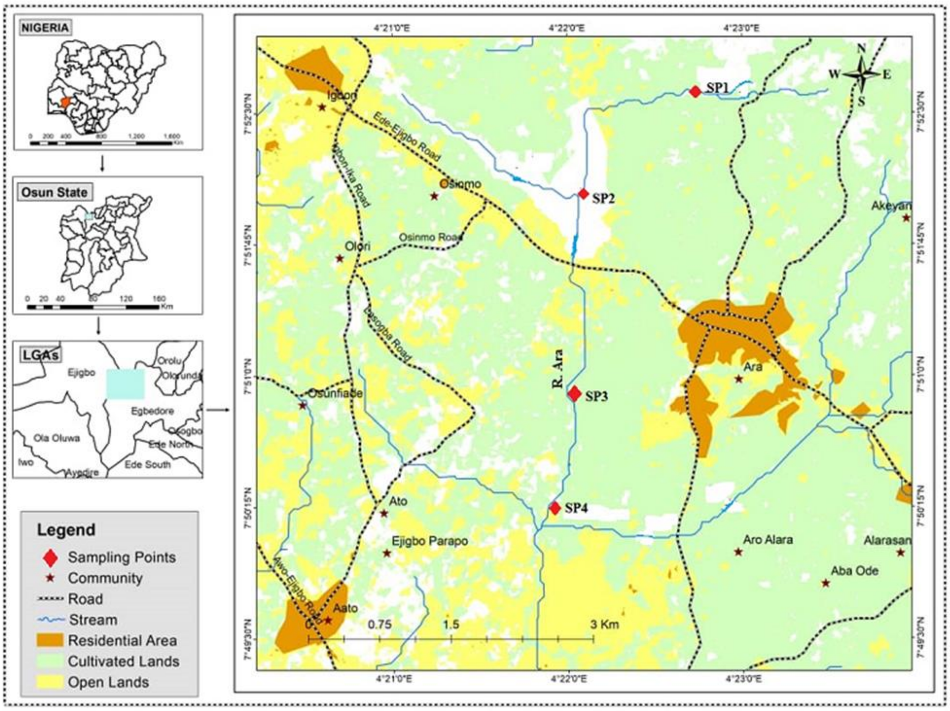


**Figure 1.** Map showing the locations of the sampling points on Ara River as well as the location of Ara in Osun state, Nigeria.

*Analysis of data*

Inferential and descriptive statistics were used to analyze data obtained for the insects and the environmental variables [19]. The environmental variables were subjected to a one-way analysis of variance (ANOVA) ($P < 0.05$). T-test was used to test for significant differences in the data obtained for the investigated environmental variables. The occurrence and abundance of aquatic insects were subjected to diversity indices such as Shannon-Weiner (H'), Simpson 1-D, Margalef, Evenness, and Equitability. All these analyses were carried out on Paleontological Statistical software (PAST). All the graphs were plotted using Microsoft Excel 2013.

## RESULTS AND DISCUSSION

A total of 344 (ind.) aquatic insects which comprised 13 genera, 10 families, and 6 orders were collected in Ara River during this study period. SP1 and SP3 accounted for 11 taxa each while SP2 and SP4 accounted for 10 and 12 taxa respectively **(Table 1)**. In terms of the abundance of insects, SP4 accounted for the highest number (128) while the least number (81) was recorded in SP3. SP1 and SP2 accounted for 81 and 72 insects, respectively. Odonata accounted for the largest number of individuals (120), thus making up 35% of the entire insect collection **(Figure 2)**. Odonata was represented by two (2) families; Libellulidae (62) and Coenagrionidae (58). Odonata is followed by Ephemeroptera which accounted for a total of 82 (23%) and distributed in two families; Caenidae (45) and Baetidae (37). Hemiptera also occurred with a significantly high number as it accounted for 79 and was distributed in three families; Belostomatidae (27), Nepidae (23), and Notonectidae (29). Trichoptera occurred with the least number (2) represented by *Cheumatopsyche* sp., and *Libellula* sp. was the dominant taxon as it accounted for the highest number (62) with a relative abundance of 18.02% while *Cheumatopsyche* sp. occurred with the least number (2) and relative abundance of 0.58%. Other taxonomic groups occurred as thus; *Appasus* sp. (6.10%), *Diplonychus* sp. (2.32%), *Ranatra* sp. (3.78%), *Laccotrephes* sp. (2.91%), *Anisops* sp. (8.43%), *Caenis* sp. (12.50%), *Cleon* sp. (10.75%), *Enallagma* sp. (9.83%), *Ischnura* sp. (6.98%), *Culex* sp. (10.17%) and *Hydrobius* sp. (7.56%).

*Richness and diversity of aquatic insects in Ara River*

The diversity of aquatic insect assemblage shows that the highest diversity indices values; Simpson1-D (0.8690), Shannon H (2.465), and

Margalef (2.671) were observed in SP4 while the least diversity indices values; Simpson 1-D (0.780), Shannon H (2.011), and Margalef (2.450) were observed in SP2. The values of Equitability obtained for the four sampling points indicated that the collected taxa were well distributed in the sampling points.

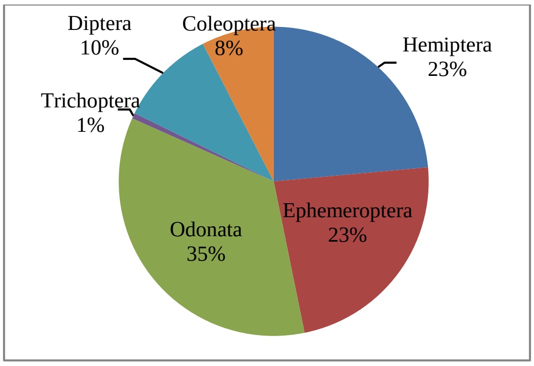


**Figure 2.** Abundance and distribution of insect orders in Ara River, Southwestern Nigeria.

**Table 1.** Absolute abundance (N) and relative abundance (ni) of aquatic insects in Ara, Southwestern Nigeria.

| Taxa | SP1 | | SP2 | | SP3 | | SP4 | | Total | Occurrence (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | ni | N | ni | N | ni | N | ni | | |
| **Hemiptera**[1] | | | | | | | | | | |
| Belostomatidae[2] | | | | | | | | | | |
| *Appasus* sp.[3] | 9 | 2.61 | 5 | 1.45 | 2 | 0.58 | 5 | 1.45 | 21 | **6.10** |
| *Diplonychus* sp.[3] | 3 | 0.87 | 0 | 0.00 | 2 | 0.58 | 1 | 0.29 | 6 | **2.32** |
| Nepidae[2] | | | | | | | | | | |
| *Ranatra* sp.[3] | 4 | 1.16 | 0 | 0.00 | 6 | 1.74 | 3 | 0.87 | 13 | **3.78** |
| *Laccotrephes* sp.[3] | 3 | 0.87 | 0 | 0.00 | 2 | 0.58 | 5 | 1.45 | 10 | **2.91** |
| Notonectidae[2] | | | | | | | | | | |
| *Anisops* sp.[3] | 8 | 2.33 | 6 | 1.74 | 5 | 1.45 | 10 | 2.91 | 29 | **8.43** |
| **Ephemeroptera**[1] | | | | | | | | | | |
| Caenidae[2] | | | | | | | | | | |
| *Caenis* sp.[3] | 14 | 4.06 | 7 | 2.03 | 6 | 1.74 | 18 | 5.23 | 45 | **12.50** |
| Baetidae[2] | | | | | | | | | | |
| *Cleon* sp.[3] | 10 | 2.91 | 6 | 1.74 | 7 | 2.03 | 14 | 4.07 | 37 | **10.75** |
| **Odonata**[1] | | | | | | | | | | |
| Libellulidae[2] | | | | | | | | | | |
| *Libellula* sp.[3] | 12 | 3.4 | 10 | 2.91 | 15 | 4.36 | 25 | 7.27 | 62 | **18.02** |
| Coenagrionidae[2] | | | | | | | | | | |
| *Enallagma* sp.[3] | 4 | 1.16 | 8 | 2.33 | 11 | 3.19 | 12 | 3.49 | 35 | **9.83** |
| *Ischnura* sp.[3] | 0 | 0.00 | 10 | 2.91 | 0 | 0.00 | 13 | 3.78 | 23 | **6.98`** |
| **Trichoptera**[1] | | | | | | | | | | |
| Hydropsychidae[2] | | | | | | | | | | |
| *Cheumatopsyche* sp.[3] | 0 | 0.00 | 2 | 0.58 | 0 | 0.00 | 0 | 0.00 | 2 | **0.58** |
| **Diptera**[1] | | | | | | | | | | |
| Culicidae[2] | | | | | | | | | | |
| *Culex* sp.[3] | 8 | 2.32 | 11 | 3.19 | 3 | 0.87 | 13 | 3.78 | 35 | **10.17** |
| **Coleoptera**[1] | | | | | | | | | | |
| Hydropphilidae[2] | | | | | | | | | | |
| *Hydrobius* sp.[3] | 6 | 1.74 | 7 | 2.03 | 4 | 1.16 | 9 | 2.62 | 26 | **7.56** |
| **Total** | **81** | | **72** | | **63** | | **128** | | **344** | **100** |

[1]Order
[1]Order
[2]Family
[3]Genus

**Table 2.** The environmental variables of the sampling points at Ara, Southwestern Nigeria.

| | AirTemp (°C) | Water temp (°C) | pH | Water depth (m) | DO (mg/L) | Flow rate (m/s) | EC (μS/cm) |
|---|---|---|---|---|---|---|---|
| **SP1** | 29.2 ± 0.04[a] | 27.5 ± 0.03[b] | 6.70 ± 0.1[a] | 0.27 ± 0.03[a] | 5.68 ± 0.02[a] | 0.38 ± 0.02[a] | 580 ± 0.51[a] |
| **SP2** | 31.5 ± 0.02[a] | 30.0 ± 0.05[a] | 7.00 ± 0.4[a] | 0.35 ± 0.03[a] | 5.01 ± 0.05[a] | 0.24 ± 0.03[a] | 656 ± 0.10[b] |
| **SP3** | 29.5 ± 0.02[a] | 29.8 ± 0.02[a] | 6.80 ± 0.3[a] | 0.31 ±0.05[a] | 4.60 ± 0.05[b] | 0.28 ± 0.02[b] | 647 ± 0.78[a] |
| **SP4** | 28.5 ± 0.05[a] | 28.0 ± 0.03[a] | 6.50 ± 0.4[a] | 0.28 ± 0.02[a] | 6.25 ± 0.03[a] | 0.45 ± 0.05[a] | 540 ± 0.43[b] |

Means followed by the same letter within the column are not significantly different (p > 0.05) using Tukey's test.

*Environmental variables*

The environmental variables investigated across the sampling points are presented in **Table 2.** Air temperature, pH, and water depth did not show significant differences in the values obtained across the sampling points while water temperature, dissolved oxygen, flow rate, and electrical conductivity showed significant variations (P > 0.05) in their values. The highest air (31.5 °C) and water temperature values (30.0 °C) were recorded in SP2 but the least air (28.5 °C) and water temperature (27.5 °C) occurred at SP4 and SP1 respectively. The highest water depth (0.35 m) was recorded at SP2 while the least (0.27 m) was recorded at SP1. The lowest pH and EC values were obtained in SP4 while the highest were obtained in SP2. The highest DO value (6.25 mg/L) and the highest flow rate (0.4 m/s) were recorded in SP4.

The cluster analysis showed a high degree of similarity between SP1 and SP4 concerning the taxonomic composition and abundance of aquatic insects recorded **(Figure 3)**. The similarity in species distribution increased with an increase in distance. While absolute similarity was observed between SP1 and SP4, about 92% level of similarity exists between SP1, SP3, and SP4. Canonical correspondence analysis revealed that many of the taxa were associated with low values of DO and high values of Flow rate **(Figure 4)**. *Diplonychus* sp., *Caenis* sp., *Cleon* sp., and *Anisop* sp. were closely associated with flow rate while *Laccotrephes* sp., *Libellula* sp., and *Enallagma* sp. were closely associated with electrical conductivity. *Hydrobius* sp. and *Culex* sp. were closely associated with dissolved oxygen but *Ranatra* sp. and *Appasus* sp. did not show close association with the environmental variables.

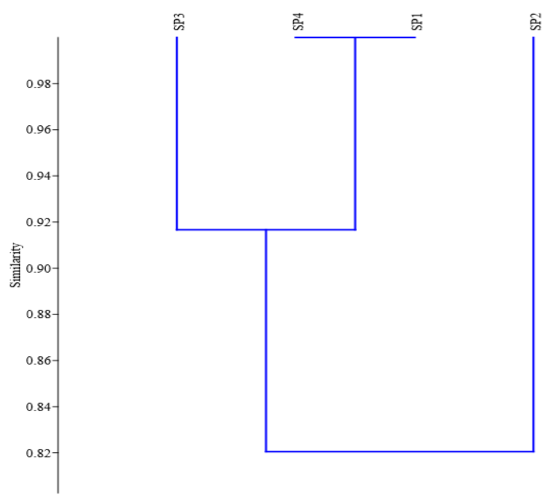


**Figure 3.** Cluster analysis shows similarities in the sampling points in terms of the taxa composition of aquatic insects.

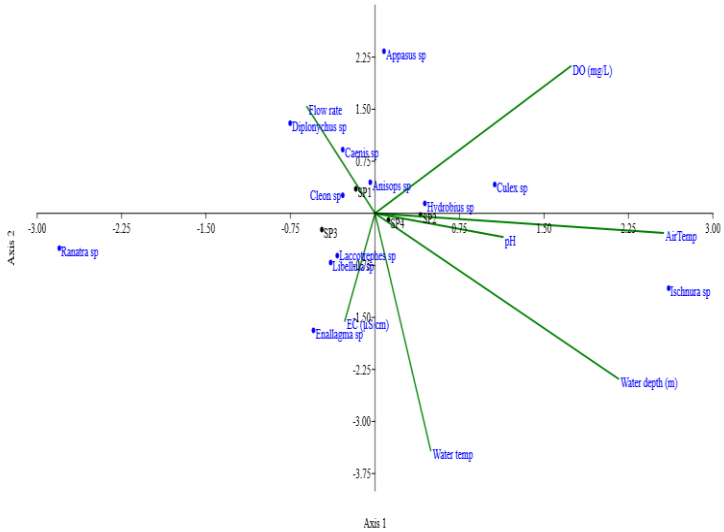


**Figure 4.** Canonical correspondence analysis showing a correlation between environmental variables and the taxa collected.

Except for electrical conductivity, the environmental variables investigated in this study did not vary significantly across the sampling points (P > 0.05). The values obtained for the physico-chemical parameters of the waterfall are within the recommended values for freshwater life by the World Health Organization [20]. The values recorded in this study also compare favorably with those reported for similar tropical inland waterbodies such as [21-23]. The observed relatively higher conductivity values recorded in SP2 could be attributed to low flow rate and high temperature. A low flow rate aids in the accumulation of salts and minerals in rivers [24] while high temperature increases solubility and ionic mobility as ions have been known to move faster in warmer water [25]. According to Buchwalter *et al.* [26], temperature is one of the most important environmental factors controlling aquatic insect density and assemblage. For instance, it has been suggested that for every 1 °C increase in temperature, conductivity will rise by 1.9% [27]. It is worth noting that the highest conductivity values were recorded in the same sampling point (SP2) with the highest air and water temperature. Similarly, temperature affects the amount of dissolved oxygen available in a particular water body [24]. Increased water temperature causes gas and water molecules to gain more energy, thus breaking weak molecular interactions between oxygen and water molecules. This ultimately leads to a reduction in the concentration of DO in a particular water body [28]. As such, the spatial variation in the concentration of DO across the sampling points may be attributed to the fluctuating water temperature in the river. It is equally worth noting that the highest concentration of DO was recorded at the sampling point (SP1) with the lowest air and water temperature. The range of pH values (6.5-7.00) obtained across the sampling points indicates the good quality of water in Ara River, as the values hover around the neutral point [9, 10]. Also reported a similar range of pH values in studies conducted on the Aahoo River and Osinmo River respectively. The two waterbodies are similar to Ara River in dimension and catchment basin activities and both are located within the Southwestern region of the country.

The aquatic insect taxa recorded in this study have been previously reported to be widely distributed in tropical inland waters such as Ogbeibu and Oribhabor [29], and Rotimi and Iloba [30]. Insects' ability to respond differently to various degrees of pollution in the aquatic environment is due to their wide range of sensitivity to pollution. This is responsible for the wide acceptance of insects as reliable bio-indicators of environmental quality [31]. Odonata dominated the insect collection in this study as it accounted for the highest number. The high number of Odonates recorded in this study was unexpected as they are rarely known to be dominant in aquatic environments. Although they have been collected in reasonable numbers in some studies, they are rarely reported to be dominant. Some studies in which Odonata have been recorded in fairly high numbers include [9, 32, 33]. Odonates have been known to be good models for the assessment of the ecological status of the environment including the aquatic ecosystem. As a result of the sensitivity of this group of insects to changes in habitat structure, they have been widely used as powerful assessment tools for both aquatic and terrestrial environments [34]. The dominance of the Odonata group in this study could be attributed to the ubiquity nature of the insect and their wide range of tolerance to pollution. A good number of the odonates recorded in this study are eurytopic species that not only tolerate mild pollution but also thrive in disturbed habitats [35].

Ephemeroptera is another group that occurred in very high numbers in this study. Members of this order of insects play a critical role in the monitoring and evaluation of water quality globally. Their large numbers and high degree of sensitivity to pollution have made them useful tools in the bio-monitoring of environmental quality. Ephemeropterans have been known to constitute a main component of the aquatic macroinvertebrate community and the main part of the biomass and production in freshwater habitats. They are also known to be pervasive in every kind of freshwater habitat [36]. The relatively high number of Ephemeroptera collected in this study may be attributed to stable substrates and the moderately high flow rate of Ara River. Stable substrate and flow rate have been identified as factors that affect the diversity of Ephemeroptera [1].

Trichoptera represented by the *Cheumatopsyche* sp. occurred as the least represented order of insect in this collection. The occurrence of this highly sensitive species is surprising as they are known to inhabit water bodies with high dissolved oxygen. However, the low number is an indication of traces of pollution in the Ara River. Trichoptera is an order of insects that are known to be highly sensitive to pollution and they are only found abundant in clean water bodies with high volumes of dissolved oxygen [37]. Another factor that could have been responsible for the low occurrence of this group of insects is the relatively high flow rate of the river. High water velocity frequently flushes away certain groups of Trichoptera especially the free-living genera that cannot withstand hydraulic stresses [38]. The abundance of *Culex* sp. (which are known to be tolerant species of insect) especially in SP4 could be an indication of point source pollution due to domestic sewage discharge into the river. Discharge of sewage causes an increase in organic matter load and reduction in the dissolved oxygen level thus making the environment more fitted for these organisms.

The insects collected in this study only showed close association with a few of the environmental variables that were investigated as revealed by the canonical correspondence analysis. This suggested that parameters such as pH, flow rate, and conductivity were the variables that significantly impacted the community assemblage of the insects.

## CONCLUSION

Water quality plays a vital role in the community assemblage of aquatic insects. Ara River was dominated by pollution-tolerant insect species. This is an indication of traces of pollution in the waterbody at the time this study was carried out. The relatively low dissolved oxygen and high conductivity values further confirmed the pollution status of the river. Efforts should be made to address the source of pollutants in the river so as not only to preserve the biodiversity in the water but to ensure the waterbody can sustain its ecological and axillary functions.

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**ETHICS STATEMENT:** None

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