

Aquatic Insects Diversity and Water Quality of a Tropical Freshwater in Federal University of Education, Ondo, Nigeria

Adeleke, S.O.¹ and Amusan, B.O.^{2*}

¹*Adeyemi Federal University of Education, Ondo, Nigeria.*

^{2*}*Obafemi Awolowo University, Ile-Ife Nigeria.*

Abstract

Aquatic insects are regarded as one of the very important components of the freshwater ecosystem because of the various ecological purposes which they serve. The insects are also the most impacted when surface waters are disturbed. As such, analyzing the structure of assemblage has become a veritable yardstick in the assessment of biodiversity and water quality. This research effort applied the combination of aquatic insect composition and physico-chemical characteristics in assessing the ecological status of Oju Awo stream. Aquatic insects and water samples were collected once in every two months covering a period between December, 2021 and October, 2022 using sweep nets and 1L sterilized bottle respectively. The results obtained for the physical and chemical parameters of the water as well as the aquatic insect assemblage showed that the investigated reaches of the stream did not differ widely except for water temperature which showed significant variations ($p < 0.05$) along the reaches of the waterbody. A total of 242 aquatic insect specimens represented by three (3) orders (Hemiptera, Odonata and Coleoptera) and sixteen (16) taxa were recorded. Hemiptera was the dominant and most abundant taxa as it accounted for about 90.91% of the total insect collection. The dominance of pollution tolerant species, the absence of sensitive insects' species and poor water quality as revealed by the physico-chemical parameters indicated deteriorating water quality conditions in the stream.

Keywords: Aquatic insects, tropical stream, abundance, diversity, water quality

INTRODUCTION

Freshwater resources are considered critical in the sustainability of life and maintenance of the balance in nature (Mahmoud, 2020). However, the inadequacy of good quality water has made it imperative to continuously assess the quality of freshwater bodies around the world. This is because most freshwater bodies are becoming deteriorated on a daily basis as a result of the influence of ever increasing anthropogenic activities (Leisher *et al.*, 2022). Furthermore, the Millennium Ecosystem Assessment revealed that many of the freshwater ecosystem species are threatened with extinction and this has been attributed to the impacts of anthropogenic activities and other related effects (Cirella *et al.*, 2019). Many countries around the world are currently confronting the challenge of managing the increasing risks and the consequential effects of temperature change

and urbanization. More critical is the fact that accessibility to clean water for its intended purposes has become problematic in many parts of the world. In Nigeria, the populace is increasingly finding it extremely difficult to access potable water due to rising volume of anthropogenic activities (Amusan and Balogun, 2019). In fact, most freshwater bodies in the country are polluted while some are gradually drying out due to exposure to pollution and other stress factors (Adenuga *et al.*, 2006). This has led to the reduction in biodiversity, destruction or degradation of the aquatic ecosystem and the life forms there in (Akindele *et al.*, 2014)

Aquatic insects also constitute the most diverse and important component of the biota in the freshwater ecosystem and this informs their importance as critical elements in the ecological dynamics of freshwater ecosystems (Folami *et al.*, 2019). Aquatic insects equally

*Correspondence email;
tundeamusan5@yahoo.com,
ORCID NUMBER: 0000-0003-1245-263X

play vital role in the cycling of materials as well as in the energy flow in the aquatic environment. Many aquatic insects are good indicators of water and environmental quality and this is as a result of their wide range of sensitivity to environmental contamination (Barman and Gupta, 2015). The members of the Orders Ephemeroptera, Plecoptera and Tricoptera (EPT) have been known to be the most sensitive to pollution, natural and anthropogenic influences in the environment (Arimoro *et al.*, 2010). This is why they are considered an integral component of structural and functional assemblages of aquatic insects (Cívik *et al.*, 2021). Also, 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 health status of freshwater ecosystems (Amusan and Balogun, 2019). Therefore, understanding the species composition and distribution pattern could be helpful in the determination of health status of waterbodies.

The application of both physico-chemical characteristics of water and structural assemblages of aquatic insects have been widely used in evaluation of the health status of several waterbodies globally. Since a significant part of the life cycle of many insects are spent in water, this has endowed them with the ability to serve as reliable bio-indicators of the ecological status of their respective habitats. Also, most aquatic insects have their specific habitat requirements, as well as varying degree of tolerance level. Therefore, the presence, absence and abundance of sensitive insects' species would provide useful information on the quality of freshwater ecosystems (Hamid and Rawi, 2017). In developed countries, many studies have successfully explored the use of aquatic insects as indicators in the assessment of water quality, but this approach is still not widely applied in Nigeria. Most studies have rather focused on the use of the physico-chemical parameters in monitoring water quality (Arimoro and Ikomi, 2008). Interestingly, the application of the combination of physico and chemical characteristics of water as well as bio-indicators in environmental assessment has recorded a good success as it has provided more reliable and precise information on the health status of waterbodies (Arimoro and Muller,

2010). Many studies have also revealed that community structure of aquatic insects potentially indicates the current status of their habitats (Prommi and Payakka, 2015). This consensus has therefore given the required impulsion for the application of both bio-indicators and physico-chemical characteristics in environmental quality assessment in Nigeria. .

Oju awo stream is one of the important water sources in Adeyemi Federal University of Education, Ondo, Southwestern Nigeria. This stream is important for fishing and also serves other domestic purposes to the people living on the campus. In spite the enormous importance of this waterbody, its water quality has never been assessed since the inception of the institution. Hence, this research sought to assess the quality of the water using a combination of the aquatic insect composition and physico-chemical characteristics of the water. This is with the aim of determining the types of ecological processes that regulates such assemblages and populations of the aquatic insects. The information obtained will help in evaluating the ecological status of Oju awo stream. The baseline information provided will also be useful in formulating management practices for the stream and similar waterbodies so as to guide against deterioration and loss of biodiversity.

MATERIALS AND METHODS

Study Area

Oju awo stream which stretches about 2km and runs through the college staff quarters, located within the campus of Federal University of Education, Ondo, Southwestern Nigeria. The stream covers Latitude 5° 45' and 7° 52'N and Longitude 4° 20' and 6° 05'E. The stream is surrounded by vegetation that is typical of the tropical rainforest region of Africa. The stream flows all years round and has an average flow velocity of 0.46m/s. For the purpose of this study, the stream was divided into three reaches as follows; Upstream, Midstream and Lower stream (Figure 1). The division was based on reach and level of exposure to anthropogenic disturbances. The three reaches are obviously exposed to varying degree of pollution loads from anthropogenic activities. While the Upper and Middle reaches receive more pollution loads, as domestic wastes are directly deposited into the stream around these two reaches, the effluents are washed into the lower reach of the

stream.

Sampling procedure, preservation and identification of aquatic insect specimens.

Collection of aquatic insects and water samples was carried out once in every two months between 8:00 – 11:00 am from December, 2021 to October, 2022.

Water samples were collected in sterilized 1L bottle. Physico-chemical parameters such as temperature, dissolved oxygen (DO), pH, electrical conductivity (EC) and total dissolved solids (TDS) was determined *in-situ* using Hanna multi-probe meter (HANNA 9828) while the other parameters were determined in the Laboratory following appropriate and standard procedures. The aquatic insect specimens were collected using long handled

D-frame and deep nets. The nets was used to scoop the surface of the marginal zone as well as within the aquatic vegetations. Hand picking method was also employed in the shallow areas of the stream. The specimens collected were kept in well labeled specimen bottles containing the stream water. The insects were sorted in white trays with the aid of a pair of forceps in the laboratory. Thereafter, the specimens were kept in specimen bottles with 75% alcohol solution as preservative. The collected insect specimens were then identified to the possible lowest taxonomic level under microscope and with the aid of appropriate and standard taxonomic identification keys and guides such as; De Moor *et al.* (2003) and Subramanian and Sivaramakrishnan (2007).

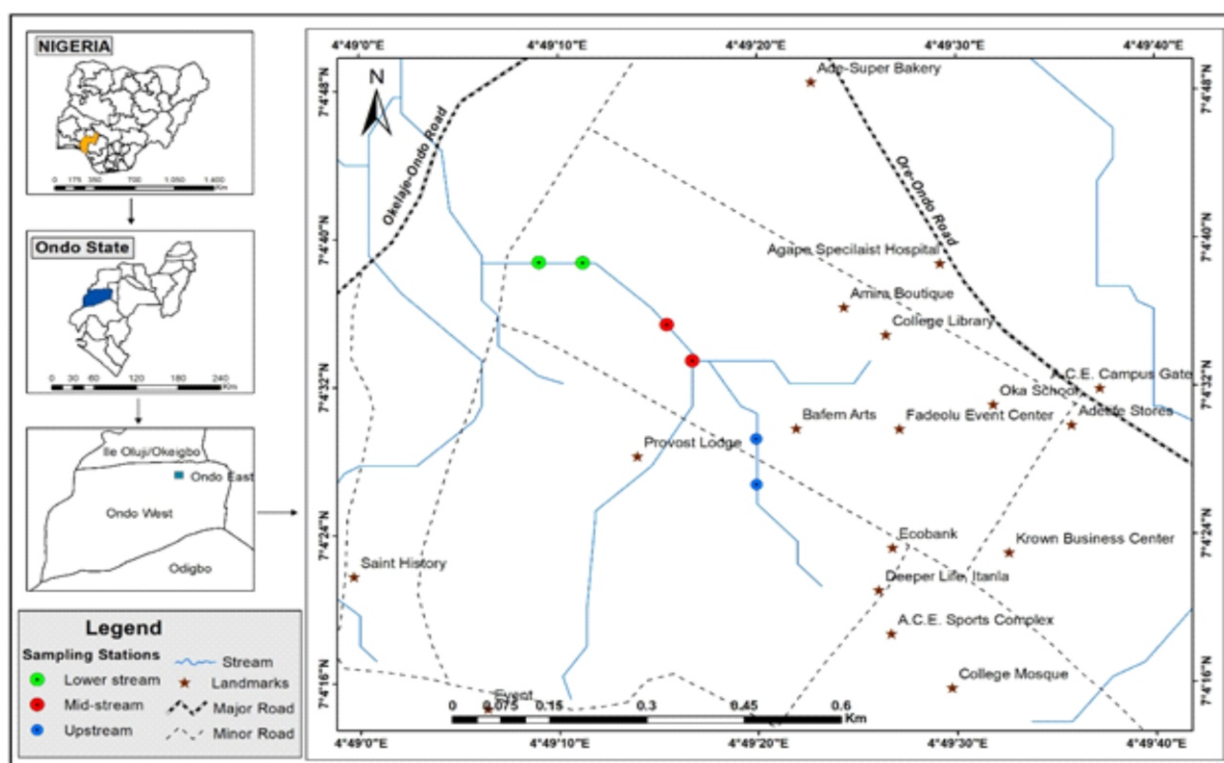


Figure 1: Map showing the locations of the sampled points on Oju awo stream, Federal University of Education, Ondo, Southwestern Nigeria.

Data analysis

Shannon wiener, Simpson (1-D), Margalef and evenness indices was used to calculate taxa richness, species diversity and richness respectively using PAST (Paleontological statistical package; version 3.0). The mean abundance of the insect orders was determined for significant differences using Kruskal - Wallis (H).

RESULTS

Physico-chemical parameters of water

The observed variations in the distribution of physico-chemical characteristics of Oju awo stream along the three reaches of the stream is as presented in Table 1. Phosphate concentration was relatively constant across the three reaches of the stream. Except for water temperature that varied significantly ($p < 0.05$,

$P = 0.01102$), the other parameters did not vary significantly along the three reaches of the stream. The highest value for water temperature ($30.25^{\circ}\text{C} \pm 1.48 / 28.70^{\circ}\text{C} - 32.85^{\circ}\text{C}$) was recorded in the lower reach while the lowest ($29.02^{\circ}\text{C} \pm 1.49 / 27.15^{\circ}\text{C} - 31.15^{\circ}\text{C}$) was recorded in the upstream. The highest values for dissolved oxygen (DO) ($7.55 \text{ mg/l} \pm 0.24 / 7.21 \text{ mg/l} - 7.94 \text{ mg/l}$), Hydrogen ion concentration (pH) ($6.82 \pm 0.59 / 6.25 - 7.60$) mg/l, Electrical conductivity (EC) ($462 \pm 500 / 130 - 1055$) $\mu\text{m/cm}$, Total dissolved solids (TDS) ($307 \pm 375 / 76.95 - 629.23$) mg/l, biochemical oxygen demand (BOD) ($1.38 \pm 0.15 / 1.20 - 1.51$) mg/l, Calcium ($39.43 \pm 31.83 / 20.85 - 72.14$) mg/l, Water hardness ($125.30 \pm 85.50 / 69.31 - 215.56$) mg/l and Nitrate ($0.99 \pm 0.45 / 0.66 - 1.73$) mg/l were recorded in the upstream while the lowest values for DO ($7.16 \pm 0.26 / 6.90 - 7.35$) mg/l, pH ($6.29 \pm 0.58 / 5.5 - 6.8$) mg/l, Calcium ($19.93 \pm 2.32 / 18.64 - 21.59$) mg/l and Nitrate ($0.70 \pm 0.32 / 0.56 - 1.16$) mg/l were recorded in the lower stream. The lowest values for EC ($243 \pm 183 / 100 - 350$) $\mu\text{m/cm}$, TDS ($144 \pm 110 / 58.61 - 210.21$) mg/l, BOD ($1.3 \pm 0.13 / 1.19 - 1.49$) mg/l and water hardness ($72.9 \pm 17.27 / 60.97 - 84.23$) mg/l were recorded in the midstream. Magnesium had its highest value recorded in the lower stream ($7.22 \pm 3.69 / 3.62 - 10.51$) mg/l while its lowest value was recorded in the midstream ($6.48 \pm 4.44 / 3.50 - 8.75$).

Composition and abundance of aquatic insects

The taxonomic composition and abundance of aquatic insects recorded in Oju awo stream is as presented in Table 2. A total of 242 specimens of aquatic insects represented by three (3) orders (Coleoptera, Hemiptera and Odonata), eleven (11) families and sixteen (16) taxa were recorded in this study. The highest species richness and abundance was recorded in the Upstream as it accounted for eight (8) taxa and 100 specimens which represented about 41.32% of the entire collection. Hemiptera was dominant in the Upstream as a total of 93 specimens were recorded in this reach of the stream representing

93% of the collection in this section of the stream (Fig. 3 and 4). Similarly, *Limnogonus* sp. (Hemiptera) was the dominant and abundant species as it accounted for 65% of the collection in upstream and 57.85% of the total insect

collection while *Amphiops* sp, *Palpopleura* sp, and *Agriocnemis* sp were the least as they accounted for one specimen each. The following species were not recorded in the Upstream section; *Donaciasta Ceriagrion*, *Pseudagrion*, *Orthetrum*, *Neochetina*, *Apassus*, *Mesovelgia* and *Nychia* sp.

The Mid-stream and lower stream accounted for a total of 88 (36.4%) and 54 (22.31%) individuals represented by 8 and 10 specimens respectively. Hemiptera was also dominant in both the Midstream and lower stream as the Order accounted for 55.68% and 48.15% of the insect collection in the reaches respectively. *Limnogonus* sp was also the dominant taxon in both midstream and lower stream. However, only three species (*Limnogonus*, *Tenagogonus* and *Anisops*) were common to both reaches (midstream and lower stream) while *Trithemis* sp. (Odonata) was common to all reaches of the stream. Some insect species were reach specific; *Amphiops* sp., *Limnogonus* sp B, and *Agriocnemis* sp. were found to be specific to the upstream; *Donaciasta* sp., *Mesovelgia* sp and *Nychia* sp were specific to the midstream while *Neochetina* sp, *Apassus* sp, *Ceriagrion* sp and *Orthetrum* sp were specific to lower stream. Some species were common to two reaches of the stream; *Pseudagrion* (midstream and lower stream) and *Palpopleura* (low stream and up stream).

Table 3 presents the mean abundance of aquatic insects recorded in this study. The populations of many of the insect species identified in this study did not vary significantly. Relatively similar numbers were recorded for the three reaches of the stream. Infact, Only *Limnogonus* sp (Hemiptera) varied significantly ($p < 0.05$) in terms of its population along the course of the stream.

Diversity and taxa richness indices

Table 4 shows the diversity of the insects recorded in this study as revealed by the diversity indices.. The highest taxa (10) was recorded in the Lower stream. The highest abundance (100) was recorded in the Upstream while the least was recorded in the Lower stream. The highest value for Simpson (1-D) (0.6927), Shannon Weiner (H) (1.543) and Margalef (2.256) indices were recorded in the Lower Stream while these least values for these indices were recorded in the Upstream.

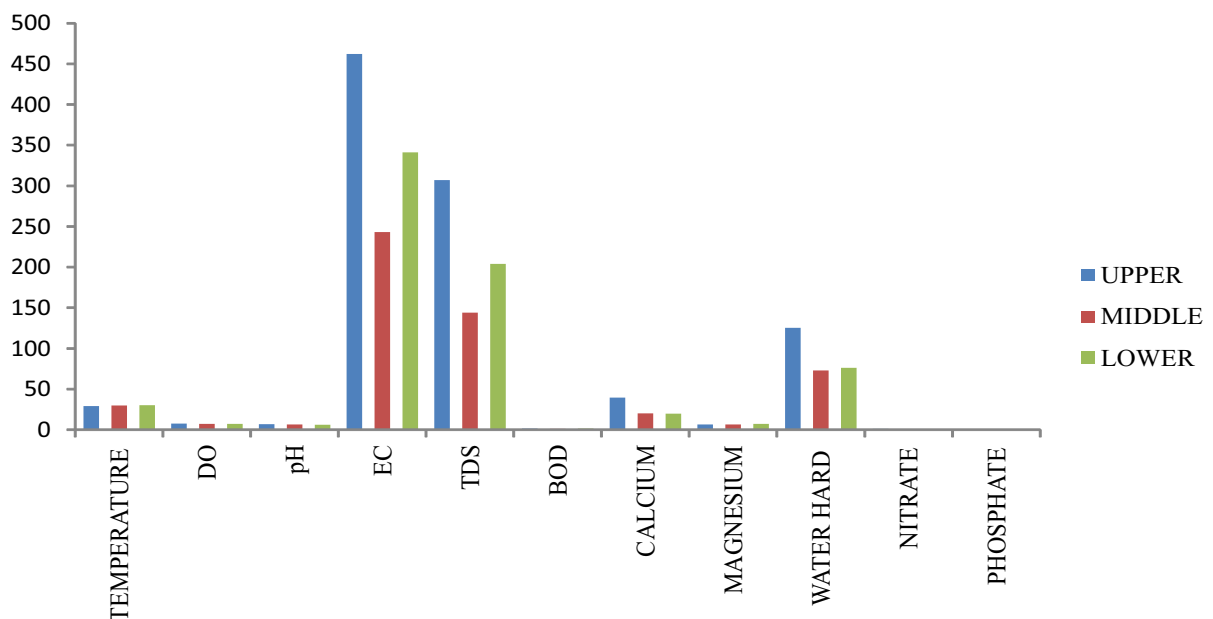
Table 1: Variations in the Physico-chemical parameters of Oju awo stream, Federal University of Education, Ondo, Nigeria.

PARAMETER S	UPSTREAM	MIDSTREAM	LOWERSTREA M	ANOVA	
				F	P
		Mean±S.d / Range	Mean±S.d / Range		
Temperature(°c)	29.02±1.49/ 27.15-31.15	29.72±1.47/ 28.20-32.25	30.25±1.48/ 28.70-32.85	6.329	0.0102*
DO (mg/l)	7.55±0.24/ 7.21-7.94	7.30±0.28/ 6.88-7.69	7.16±0.26/ 6.90-7.35	0.4939	0.6205
pH	6.82±0.59/ 6.25-7.6	6.40±0.54/ 5.7-7.0	6.29±0.58/ 5.5-6.8	1.408	0.2772
EC (µs/cm)	462±500/ 130-1055	243±183/ 100-350	341±234/ 160-635	0.562	0.6134
TDS (mg/l)	307±375/ 76.95-629.23	144±110/ 58.61-210.21	204±141/ 94.44-382.53	0.3956	0.6806
BOD (mg/l)	1.38±0.15/ 1.20-1.51	1.3±0.13/ 1.19-1.49	1.37±0.13/ 1.29-1.47	0.3043	0.7424
Calcium (mg/l)	39.43±31.83/ 20.85-72.14	20.30±1.86/ 18.64-23.07	19.93±2.32/ 18.64-21.59	0.7445	0.4929
Magnesium (mg/l)	6.71±4.26/ 3.74-12.01	6.48±4.44/ 3.50-8.75	7.22±3.69/ 3.62-10.51	1.984	0.1744
Water Hardness	125.30±85.50/ 69.31-215.56	72.94±17.27/ 60.97-84.23	76.09±16.25/ 65.15-96.14	1.039	0.3796
Nitrate (mg/l)	0.99±0.45/ 0.66-1.73	0.91±0.30/ 0.60-1.25	0.70±0.32/ 0.56-1.16	0.7397	0.495
Phosphate (mg/l)	0.13±0.00/ 0.00-0.13	0.13±0.00/ 0.00-0.13	0.13±0.00/ 0.00-0.13	1.255	0.3154

*Significant difference $p < 0.05$ *; $p < 0.01$ **, $p < 0.001$ ****

Table 2: Composition and relative abundance of aquatic insects in Oju awo stream, Federal University of Education, Ondo, Nigeria

Taxa	Stream Reaches			Total
	Up stream	Mid stream	Lower stream	
Coleoptera				
<i>Donaciasta sp.</i>	0	1(1.14%)	0	1(0.41%%)
<i>Neochetina sp.</i>	0	0	1(1.85%)	1(0.41%)
<i>Amphiops sp.</i>	1(1.0%)	0	0	1(0.41%)
Sub total	1(1.0%)	1(1.14%)	1(1.85%)	3(1.24%)
Hemiptera				
<i>Apassus sp.</i>	0	0	1(1.85%)	1(0.41%)
<i>Limnogonus sp.</i>	65(65%)	49(55.68%)	26(48.15%)	140(57.85%)
<i>Limnogonus sp. B</i>	7(7%)	0	0	7(2.89%)
<i>Tenagogonus sp.</i>	18(18%)	24(27.27%)	13(24.07%)	55(22.73%)
<i>Mesovelvia sp.</i>	0	1(1.14%)	0	1(0.41%)
<i>Anisops sp.</i>	3(3%)	6(6.82%)	6(11.11%)	15(6.20%)
<i>Nychia sp.</i>	0	1(1.14%)	0	1(0.41%)
Sub total	93(93%)	81(92.05%)	46(85.19%)	220(90.91%)
Odonata				
<i>Ceriagrion sp.</i>	0	0	1(1.85%)	1(0.41%)
<i>Pseudagrion sp.</i>	0	1(1.14%)	1(1.85%)	2(0.83%)
<i>Orthetrum sp.</i>	0	0	1(1.85%)	1(0.41%)
<i>Palpopleura sp.</i>	1(1%)	0	1(1.85%)	2(0.83%)
<i>Trithemis sp.</i>	4(4%)	5(5.68%)	3(5.56%)	12(4.96%)
<i>Agriocnemis sp.</i>	1(1%)	0	0	1(0.41%)
Sub total	6(6%)	6(6.82%)	7(12.96%)	19(7.85%)
Total	100	88	54	242

**Figure 2:** Variations in the physico -chemical parameters of Oju awo stream, Federal University of Education, Ondo, Nigeria.

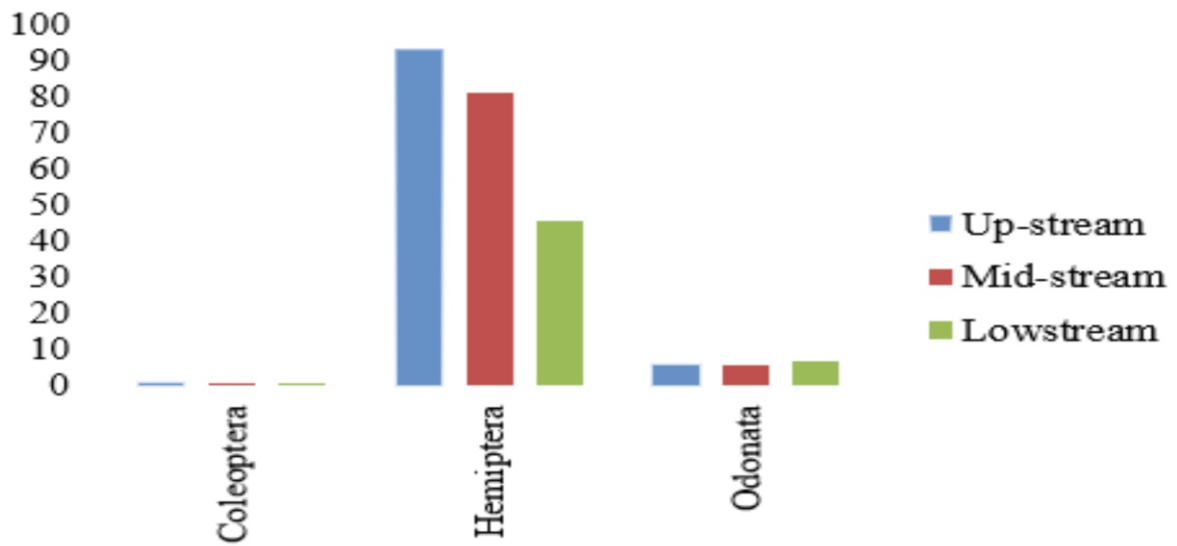


Figure 3: Abundance of aquatic insects (Orders) in the three reaches of Oju-awo stream, Federal University of Education, Ondo, Nigeria.

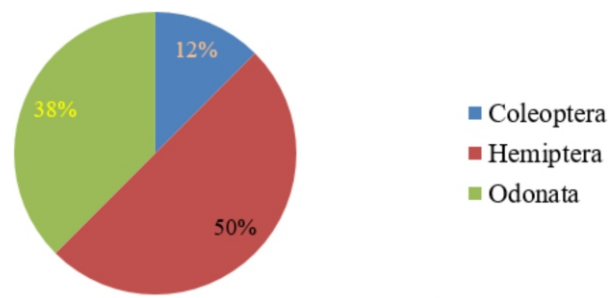


Figure 4: Diversity (Order) of aquatic insect orders in Oju-awo stream, Federal University of Education, Ondo, Nigeria.

Table 3: Mean abundance of aquatic insects in Oju awo stream, Federal College of Education, Ondo, Nigeria.

Taxa	Upstream	Midstream	Lower stream	KRUSKAL-WALLIS	
				H	P
<i>Donaciasta sp</i>	0	0.17±0.4	0	0.7895	0.9777
<i>Neochetina sp</i>	0	0	0.17±0.4	0.7895	0.9777
<i>Amphiops</i>	0.17±0.4	0	0	0.7895	0.9777
<i>Apassus sp.</i>	0	0	0.17±0.4	0.7895	0.9777
<i>Limnogonus sp</i>	10.83±4.45	8.17±3.11	4.33±1.51	5.871	0.3189
<i>Limnogonus sp. B</i>	1.67±2.86	0	0	0.7895	0.9777
<i>Tenagogonus sp</i>	3.00±1.41	4.33±3.39	2.17±1.47	12.09	0.03353*
<i>Mesovelgia sp</i>	0.17±0.41	0	0	0.7895	0.9777
<i>Anisops sp</i>	0.50±0.55	1.00±0.89	1.00±0.89	10.69	0.5788
<i>Nychia sp</i>	0.17±0.41	0	0	0.7895	0.9777
<i>Ceriagrion sp</i>	0	0	0.17±0.41	0.7895	0.9777
<i>Pseudagrion sp</i>	0	0.17±0.41	0.17±0.41	1.263	0.9387
<i>Orthetrum sp</i>	0	0	0.17±0.41	0.7895	0.9777
<i>Palpopleura sp</i>	0.17±0.41	0	0.17±0.41	3.111	0.6829
<i>Trithemis sp</i>	0.67±0.52	0.83±0.72	0.50±0.55	10.73	0.05711
<i>Agriocnemis sp</i>	0.17±0.41	0	0	0.7895	0.9777

Table 4: Diversity and taxa richness indices of aquatic insects in Federal University of Education, Ondo, Nigeria.

	Upper-stream	Middle-stream	Lower stream
Taxa Richness	8	8	10
Abundance	100	88	54
Simpson (1-D)	0.5374	0.6072	0.6927
Shannon Index (H)	1.147	1.23	1.543
Margalef	1.52	1.563	2.256
Evenness _{e^H/S}	0.3936	0.4276	0.4677

DISCUSSION

The results of the physico-chemical analysis of Oju awo stream compared favourably with values reported for studies in similar waterbodies in the Afrotropical region such as Oku *et al.* (2014), Adu *et al.* (2019) and Amusan and Balogun (2019) and Komolafe and Imobe (2022).

Variations in physico-chemical parameters have been identified as an important factor that potentially determines the distribution pattern of insects in water bodies. Although, there were observed differences in the physico-chemical

parameters in the three reaches of the stream, however the variations did not vary statistically ($p > 0.05$). Except for the water temperature which showed significant difference ($p < 0.05$) in its values across the three reaches of the stream, the other parameters were not significantly different. This suggested that the reaches of the stream were not widely different in terms of their water quality. The values obtained fell below the permissible limits for aquatic life as prescribed by the World Health Organization WHO (2022).

The observed relatively higher conductivity

values especially in the Upstream could be attributed to high water temperature and low flow rate due to direct dumping of domestic refuse at this section of the stream. The refuse dump blocks the flow pathway of the stream and prevents the water from flowing freely. Low flow rate aids accumulation of salts and minerals in rivers (Paramita, 2015) while high temperature increases solubility and ionic mobility as ions are known to move faster in warmer water (Sergum *et al.*, 2022). According to Buchwalter (2019), the temperature of water temperature is a major factor that limits the quality of life and habitats and ultimately determines the density and community structure of aquatic insect. Nnoli *et al.* (2019) reported that for every 1°C increase in temperature, conductivity will rise by 1.9%. Similarly, temperature affects the amount of dissolved oxygen available in a particular water body. Increased water temperature helps gas and water molecules to gain more energy, thus breaking weak molecular bond between oxygen and water molecules and this lead to reduction in the concentration of DO in a particular waterbody (Aronne, 2021). As such, the observed variation in the concentration of DO along the reaches of the stream might have been brought about by the significant differences in the temperature of the water along the three reaches of the stream (Sergum *et al.*, 2022).

Deteriorating physico-chemical characteristics of water have been known to be one of those factors that determines the species composition and structure of assemblages of insects in freshwater ecosystem (Arimoro *et al.*, 2015). As such, the high Water temperature, EC, BOD and TDS in this study indicated a distressed watercourse. This is attributable to uncontrolled anthropogenic influences on the stream. The low DO concentration in the three reaches of the stream was also an indication of the presence of pollution loads in the waterbody. Refuse dumps and run-off from nearby agricultural land may suggest the likely sources of the pollutants in the water.

The insect taxa recorded in this study have been previously reported in similar waterbodies in tropical inland waters such as Yapo *et al.* (2013), Nasiruddin *et al.* (2014) and Amusan and Balogun (2019). However, abundance and diversity of the insects in this study is quite low when compared to what has been reported for

some previous studies conducted in similar waterbodies (Barman and Gupta, 2015; Akamagwuna *et al.*, 2019, Ogiadiaka *et al.*, 2021).

Hemiptera dominated the insect collection and was the most abundant taxa as it constituted about 50% of the entire insect collection. This Order was fairly represented in the three reaches of the stream but the highest number was recorded in the Upstream while the least was recorded in the Lower stream. Dominance and abundance of Hemiptera have been reported in studies such as; Naranjo *et al.* (2010), Prakash and Verma (2020). The abundance of Hemiptera in this study may be attributed to availability of good quality food and suitable oviposition sites provided by aquatic vegetation (Arimoro *et al.*, 2015). Many species in the Order Hemiptera feed majorly on mosquitoes. The abundance of mosquito larvae due to slow flow rate of the stream provides choice food materials for the Hemipterans. The modified body structure of most Hemiptera species also conferred on them a great ability to survive in a diverse habitats (good and polluted waterbodies). For instance, water skaters have tiny hairs on their feet with which they can trap air. As such, they can stay and walk on the surface of water taking advantage of the atmospheric air without necessarily depending on dissolved oxygen in water. This implies that Hemiptera can thrive in aquatic environments with low amount of dissolved oxygen.

Odonata was the order with the second highest abundance and was recorded across the three reaches of the stream. Odonates have been known to be tolerant species and have ability to withstand disturbed waterbodies with their good adaptation potentials (Adu *et al.*, 2019). The fairly abundance of Odonata in this study may be attributed to the variation in their feeding styles and the presence of abundant riparian vegetations which provide oviposition sites for members of Odonata (Arimoro *et al.*, 2015).

It is worth noting that sensitive insect species especially members the EPT group were totally absent in this collection. The members of the EPT complex are highly sensitive insect species which are found predominantly in good water quality with considerably high concentration of

dissolved oxygen. The absence of these highly sensitive insect species suggests traces of pollution in the stream.

Diversity indices showed that the stream is distressed. The diversity (as indicated by the diversity indices) in the stream is relatively low. The average Margalef value obtained for the three reaches of the stream is considerably low and less than 3. As it has been previously reported by Lenat *et al.* (1980), Margalef index value that is greater than 3 is suggestive of a clean water condition while values less than 1 may suggest polluted waterbody. However, the average value indicated by Margalef is 1.78. This implied that there was a moderate amount of pollution in Oju awo stream as at the time the study was carried out.

CONCLUSION

This study has shown that the health of the water body of Oju awo has been compromised as revealed by the abundance of pollution tolerant species, poor water quality and structural assemblage of aquatic insects. The absence of sensitive insects' species in the orders Ephemeroptera, Plecoptera and Trichoptera (EPT) and the low Margalef's index value further indicated deteriorating water quality conditions. The uncontrolled anthropogenic activities around the stream had contributed to the pollution load in the stream. Stringent regulations to control anthropogenic activities around the stream in order to enable the stream sustain the provision of desired and valued ecological services should be encouraged.

ACKNOWLEDGEMENT

The authors appreciate the Head, Department of Biology, Adeyemi Federal University of Education, Ondo for granting access to Laboratory facilities in the Department.

REFERENCES

- Adenuga, A. O., Ogunjiuba, K. and Obuche, F. K. (2006).** Sustainability of the Environment and Water Pollution in Nigeria: Problems, Management and Policy Options. *Global journal of environmental sciences*, 5: 49-59.
- Adu, W. B., Amusan, B. O. and Oke, T. O. (2019).** Assessment of the water quality and Odonata assemblages in three waterbodies in Ilara-Mokin, Southwestern Nigeria. *International Journal of Odonatology*, 22 (2): 101-114.
- Akamagwuna, F. C., Mensah, P. K., Nnadozie, C. F. and Odume, O. N. (2019).** Traits-based responses of Ephemeroptera, Plecoptera and Trichoptera to sediment stress in the Tsitsa River and its tributaries, Eastern Cape, South Africa. *River Research and Applications*, 35(7): 999–1012.
- Amusan, B. and Balogun, I. (2019).** Assessment of the aquatic insect assemblage and water quality of a tropical stream in southwestern Nigeria. *Journal of Entomology and Zoology studies*, 7(1): 1199-1205.
- Akindele, E. O., Adu, B. W. and Ayandele, M. A. (2014).** Hydrology and water quality characteristics of a stressed lotic freshwater system in southwest Nigeria. *Tropical Freshwater Biology*, 23, 1–19.
- Arimoro, F. O. and Ikomi, R. B. (2008).** Response of macroinvertebrate communities to abattoir wastes and other anthropogenic activities in a municipal stream in the Niger Delta, Nigeria. *Environmentalist*, 28:85-98.
- Arimoro, F. O. and Muller, W. J. (2010).** Mayfly (Insecta: Ephemeroptera) community structure as an indicator of the ecological status of a stream in the Niger Delta area of Nigeria. *Environmental Monitoring Assessment*, 166, 581–594.
- Arimoro, F. O., Odume, N. O., Uhunoma, S. I. and Edegbene, A. O. (2015).** Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environmental Monitoring Assessment*, 187: 1-14.
- Aronne, G., Iovane, M., and Strumia, S. (2021).** Temperature and humidity affect pollen viability and may trigger distyly disruption in threatened species. *Ann Di Bot.* 1:77-82
- Barman, B. and Gupta, S. (2015).** Aquatic insects as bio-indicator of water quality- A study on Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India. *Journal of Entomology and Zoology studies*, 3(3): 178-186.

- Buchwalter, D. B., Resh, V. H., Lamberti, G. A. and Verberk, WCEP. (2019).** Aquatic insect respiration In: Merritt WCEP, Cummins KW, Berg MB (Eds.), An Introduction to the Aquatic Insects of North America 5th Edition, Kendall/Hunt Dubuque Iowa.
- Cibik, J., Beracko, P., Krno, I., Lánczos, T., Navara, T. and Derka, T. (2021).** The taxonomical and functional diversity of three groups of aquatic insects in rheocrene karst springs are affected by different environmental factors. *Limnologica*. 91. 12-19.
- Cirella, G., Iyalomhe, F. and Adekola, O. (2019).** Determinants of Flooding and Strategies for Mitigation: Two-Year Case Study of Benin City. *Geosci*. 9:130-136.
- De Moor, I. J., Day, J. A. and De Moor, F. C. (2003).** Guides to the freshwater invertebrates of Southern Africa, vol. 7. In *Insecta 1 (Ephemeroptera, Odonata and Plecoptera) TT*, (p. 300). Pretoria: Water Research Commission.
- Folami, A. M., Enitan, I. T. and Swalaha, F. M. (2019).** Surface Water Pollution by Open Refuse Dumpsite in North Central of Nigeria. *International Journal of Environmental and Ecological Engineering* 13(8):564-567.
- Garba, F., Ogidiaka, E. Akamagwuna, F. C., Kehi, H. and Edegbene, A. (2022).** Deteriorating water quality state on the structural assemblage of aquatic insects in a North-Western Nigerian River, *Water Science*, 36:1, 22-31.
- Hamid, S. and Rawi, C. S .M. (2017).** Application of aquatic insects (Ephemeroptera, Plecoptera and Trichoptera) in water quality assessment of Malaysian headwater. *Tropical Life Sciences Research* 28(2):143.
- Komolafe, B. O. and Imoobe, T. O. T. (2022).** Aquatic insects diversity and water quality assessment of a tropical freshwater pond in Benin City, Nigeria. *J. Appl. Sci. Environ. Manage.* 24(7): 1129-1136.
- Leisher, C., Robinson, N., Brown, M., Kujirakwinja, D., Schmitz, C. M., Wieland, M. and Wilkie, D. (2022).** Ranking the direct threats to biodiversity in sub-Saharan Africa. *Biodivers. Conserv.* 31:1329-343.
- Lenat, D. R., Smock, L. A. and Penrose, D. L. (1980).** Use of Benthic Macroinvertebrates as Indicators of Environmental Quality. *Biological Monitoring for Environmental Effects*, Lexington Books, Toronto, Canada, 7-114
- Mahmoud, M. A. and Riad, S. A. (2020).** Ecological studies on some aquatic insects in the Damietta branch, River Nile of Egypt as bioindicators of pollution. *Egyptian Journal of Aquatic Biology and Fisheries*, 24(4):57-76.
- Naranjo, C. Riviaux, S. M., Moreira, F. F. F. and Court, R. C. (2010).** Taxonomy and distribution of aquatic and semiaquatic Heteroptera (Insecta) from Cuba. *International Journal of Tropical Biology*. 58: 897-907.
- Nasiruddin, M., Azadi, M. A. and Reza, M. S. (2014).** Abundance and diversity of aquatic insects in two water bodies of Chittagong University campus. *Bangladesh Journal of Zoology*, 42(1): 19-33.
- Nnoli, H., Kyerematen, R., Adu-Acheampong, S. and Julian, H. (2019).** Change in aquatic insect abundance: Evidence of climate and land-use change within the Pawmpawm River in Southern Ghana. *Cogent Environmental Science*. 5:1: 1594511.
- Ogidiaka, E., Ikomi, R. B, Akamagwuna, F. C. and Edegbene, A. O. (2021).** Exploratory accounts of the increasing pollution gradients and macroinvertebrates structural assemblage in an Afrotropical estuary. *Biologia* 32: 145-148.
- Oku, E. E., Andem, A. B., Arong, G. A. and Odjajare, E. (2014).** Effect of Water Quality on the Distribution of Aquatic Entomofauna of Great Kwa River, Southern Nigeria. *American Journal of Engineering Research*, 3(1): 265-270.
- Paramita, I., Yuli-Herawati, E. and Sudaryanti, S. (2015).** Composition and abundance of aquatic insects in Jurang Susuh Stream, Batu City, Indonesia. *J. Life Sci Biomed.* 5(5):120-6.
- Prakash, S. and Verma, A. K. (2020).** Diversity of aquatic insects in relation to physico-chemical parameters of two

- water bodies of Balrampur Distric (U.P), India. *International Journal of Entomology Research*, 5(2):24-28.
- Prommi, T. and Payakka, A. (2015).** Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. *Sains Malaysiana*, 44(5), 707–717.
- Sergun V., Gorbushina, I., Valentina, B., Poznyakovsky, V., Tokhiriyon., B. & Lapina, V. (2022).** The Use of the New Dietary Supplement with Lake Salts in Treating Primary Dysmenorrhea. *Int J. Pharm Res Allied Sci.* 11(3): 66-70.
- Subramanian, K. A. and Sivaramakrishnan, K. G. (2007).** Aquatic Insects of India. A field guide. *Ashoka Trust for Ecology and Environment, Bangalore, India.* 62.
- WHO (2022)** World Health Organization. Guidelines for drinking-water quality: incorporating first addendum Vol. 4. Recommendations. – 3rd ed. 20 Avenue Appia, 1211. Geneva. 27, Switzerland. 2022.
- Yapo, L. M., Atse, C. B. and Kouassi, P. (2013).** Composition, abundance and diversity of aquatic insects in fishponds of southern Ivory Coast, West Africa. *Faunistic Entomology*, 66: 123-133.

