Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Environmental effect of resort centres on the distribution of aquatic insect fauna in Ethiope River, Delta State, Nigeria

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ARTICLE INFO

ABSTRACT

Objective: To assess water quality and diversity of aquatic insects relative to effluents discharge from resort centres in Ethiope River.
Methods: Water samples collected from three study stations were analyzed using APHA methods while the kick sampling techniques were used for collection of aquatic insects. The obtained data were subjected to statistical analysis at significance level of 0.05.
Results: Among the study stations, water temperature varied from 20 °C to 34 °C with a mean temperature of (26.17 ± 2.37) °C, while pH was recorded from 5.57 ± 0.18 to 5.94 ± 0.21. Statistically, water temperature, pH, dissolved oxygen and conductivity were significantly different ($P < 0.05$) among months. A total of 14 taxa comprising 300 individuals belonging to orders of Odonata, Coleoptera, Hemiptera, Plecoptera, Ephemeroptera and Diptera were recorded. There was significant difference in the overall insect diversity among the stations. Ephemeroptera was the largest and the most dominant order having 55.33% species, followed by the Odonata (15.33%), Coleoptera (9.67%) and Diptera (9.67%), Hemiptera (7%) and Plecoptera (3%). Shannon–Wiener and Evenness index were not significant ($P > 0.05$) in the stations.
Conclusions: Significant relationships were recorded between water quality parameters and occurrence of *Neoperla spio, Caenis horaria, Baetis* and *Chironomus* species. The observed changes in aquatic insect composition were principally due to alteration in water quality. The weak correlation between aquatic insects and water quality can be attributed to functional adaptations to environmental changes. Aquatic insects have been proved to be good bio-indicator of pollution and long-term monitoring of the aquatic insects is necessary for water quality evaluation in Ethiope River.

1. Introduction

Aquatic insects are macroinvertebrates that live on or associated with bottom of freshwater bodies[1]. Their pivotal role in nutrients circulation cannot be over emphasized in aquatic environment. Aquatic invertebrates are the link between unobtainable nutrients in detritus and protein materials in fishes[1,2]. Their role in fast-tracking the breakdown of putrefying organic material into smaller inorganic forms such as nitrate and phosphate is also well

documented[3]. These nutrients are usually utilized by aquatic plants in the ecosystem.

Aquatic insects commonly used as biological indicator have been effective in monitoring environmental pollution and water quality[4,5]. The sensitivity and forbearance to environmental perturbation exhibited by aquatic insects vary considerably among orders and species. The composition and distribution of aquatic insect at any given point in a water course is a reflection of its water quality[5]. This makes aquatic insect a valuable tool in pollution and water quality assessment. Species richness of aquatic insects can be influenced by physicochemical parameters [temperature, dissolve oxygen (DO), biochemical oxygen demand (BOD) and turbidity] of water. The structural composition of insect communities has been the focus of many researches on aquatic system. The mere presence or absence of an individual of a species provides little information of

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existing water condition. The qualitative and quantitative changes in the entire community are of great importance[6]. The use of aquatic insect as bio-indicator has been advocated by many investigators[7,8].

Different biological elements, together with physicochemical variables from water and sediments, have been monitored in several rivers in Delta State, but no attention has been paid to the pollutions from the resort centres along the course of Ethiope River. The data obtained were used to analyze the response of these ecosystems to the sewage disposed into the river from the resort centres. No sewerage plan has been made to curb the discharge of effluents from the resort centres and Delta State University hostels into the river. Effluents and anthropogenic waste discharged into Ethiope River and associated response of aquatic insect underscore the need for this study. This study was aimed to identify significant changes in the composition distribution and density of aquatic insects due to effluent. Specifically, this study shall (i) characterize water quality, (ii) identify structural composition of aquatic insects in the effluent discharge point and (iii) give a comparative account of the ecological characteristics of the resort centres, with a view to ameliorating effects of this effluent on aquatic insect in Ethiope River, Delta State, Nigeria.

2. Materials and methods

2.1. Description of study area

Ethiope River (Figure 1), a tributary of Benin River, is located in Delta State, Nigeria. It has its source at Umuaja in Ukwani Local Government Area of Delta State and is situated between longitude of 5°50' E to 6°10' E and latitude of 5°10' N to 5°20' N. The river serves as the main drainage system of the riparian communities accounting for most of the total water runoff. The river is characterized with heavy organic pollution originating from kitchen, laundry as well as anthropogenic waste from the resort centres and hostels, which is continuously discharged without proper treatment. The river covers a distance of about 180 km and flows into Atlantic Ocean through the Forcados River. The climate of the location of the river is typically tropical with two distinct (dry and rainy) seasons. As a result of climatic factors, the vegetation of Ethiope River is divided into macrovegetation and microvegetation which are the visible plants in the water and on the land. The river serves as a resort centre and tourist attraction especially at its source where there is the belief by the "Igbe-juju worshippers" that the water flows from a big Iroko tree (*Milicia excelsa*).
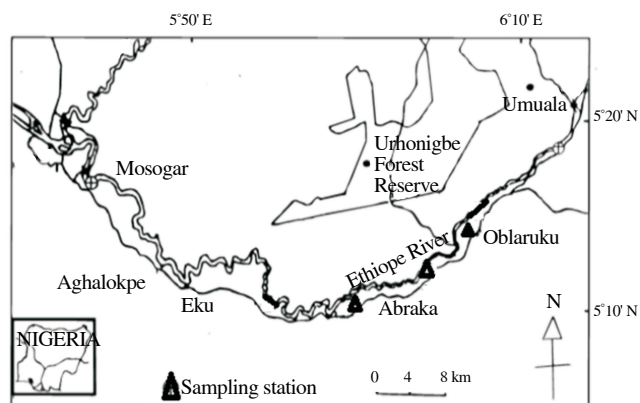

Figure 1. Map of sampling locations in Ethiope River.

Station 1 is located at Abraka, Benin Road at Urhuoka area. The area has various plants such as the *Dryopteris* sp., *Bambusa vulgaris, Azolla* species and water lilies. Also various fishes such as tilapia, *Calamachthys etc.* are found at this station. McCathy Beach (a resort centre) is very close to this station, which was the reference point for this study with a mean water depth and width of 0.85 m and 100 m, respectively.

Station 2 is a site affected by pollution, which is located behind Delta State University, Abraka, very close to Rivotel Resort. It is a swampy area with less than 100% transparency. The vegetation is comprised of various plants such as *Bambusa vulgaris* and *Azolla* species and the area is surrounded by thick forest with tall trees which serve as shade to some parts of the area. A resort centre is also located close to this site and is about 200 m away.

Station 3 is located at the golf turf club at Oria Abraka which is downstream of the Ethiope River. It is quite different from the other stations; its substratum is sandy with sparse vegetation characterized with tall trees. The transparency is about 100%. The prevalent vegetation at the bank includes *Panicum maximum*, *Bambusa vulgaris* and *Pistia stratiotes.*

2.2. Assessment of water quality

Monthly water samples were obtained from three sampling sites between May and October 2014 along the river course. Water temperatures, pH, DO, BOD_5 conductivity, and total alkalinity were determined in accordance with APHA methods[9]. Other parameters like phosphate-phosphorus (PO_4-P), nitrate-nitrogen (NO_3-N) and sulphate were measured spectrophotometrically after reduction with appropriate solutions[9]. The metallic (Ca and Fe) parameters were analyzed with atomic absorption spectrometer after initial pretreatment with HNO_3 acid. These physicochemical parameters were analyzed almost immediately to minimize chemical changes in the sample. All parameters were measured in mg/L except temperature (°C), depth (m) and conductivity (μs/cm).

2.3. Sampling and identification of aquatic insects

The modified kick sampling technique adopted from Ikomi and Arimoro[10] was used in collecting aquatic insects from the plants at the river bank of each station. Samples were collected by vigorously disturbing the substratum and emergent vegetation in a designated area of 0.25 m² by kicking for about 10 min. Aquatic insects were collected monthly from each sampling station with the use of a hand net (154 μm mesh size) for a period of 6 months. The net was held with the opening facing upstream so that insects were carried into it by the water current. Aquatic insects were sorted according to stations and preserved in 70% ethanol in laboratory prior to taxonomic identification based on larval head capsules, antennae and labial plates[11-13].

2.4. Statistical analysis

Laboratory data of water quality and aquatic insect fauna were subjected to statistical analysis following methods of Ogbeibu[14] and Magurran[15]. The *t*-test and ANOVA were used, and Shannon diversity index (H'), Spearman correlation, taxa richness, diversity and evenness indices were computed with 2003 Microsoft Excel

Package. Aquatic insect abundance was obtained by counting all individuals in a taxon and the results were expressed as number. Simpson dominance index was used to compare the abundance of the most common insect species in each station.

3. Results

3.1. Physicochemical parameters

The data for physicochemical parameters in each sampling station during the period of study (May to October 2014) are presented in Table 1. The monthly water temperature for this study ranged from 20 ℃ to 34 ℃ as shown in Table 1 with no significant difference ($P > 0.05$) in stations.

The monthly water depth varied from 0.68 to 1.32 m (Table 1). In all stations, water depth (m) was higher in the later months of sampling than the early sampling months. There was no significant difference ($P > 0.05$) in stations. pH values varied from 5.12 to 7.20 (Table 1) with its peak in September in Station 2. ANOVA showed that there was no significant difference ($P > 0.05$) in the months and stations.

Electrical conductivity was significantly different ($P < 0.05$) in the months and stations. However, Station 1 recorded the highest value in the month of May while the lowest value of 4.70 μs/cm was recorded in Station 3 in the month of July (Table 1).

The concentrations of all the chemical parameters including DO, BOD_5, phosphate, nitrate, alkalinity, iron and calcium (Table 1) analyzed in this study were not significantly ($P > 0.05$) different in stations except for sulphate ($P < 0.05$) (Table 1). However, DO values varied from 4.91 to 7.90 mg/L (Table 1) with a significant difference in months. DO had its peak value of 7.90 mg/L in Station 3 in the month of May while the lowest value was 4.91 mg/L in the month of June in Station 3. BOD value had its peak at 3.01 mg/L in October in Station 3 while

Station 1 had the lowest value of 2.00 mg/L in August.

3.2. Analysis of aquatic insect assemblages

Table 2 showed that the order Odonata was dominated by *Aeshna* sp., *Libellula* sp., *Gomphus* sp. while Ephemeroptera was dominated by *Baetis* species, *Caenis horaria*, *Cloeon dipterum* and *Centroptilum* sp. which were the most abundant species contributing about 57% of the total aquatic insects. Fourteen different species belonging to 6 taxonomic orders and 300 individuals were captured in the present study. The study further revealed that 146, 75 and 79 individuals were recorded in Stations 1, 2 and 3 respectively as shown in Table 2.

Table 2

Spatial composition and distribution of aquatic insect in sampling point from May to October, 2014 in Ethiope River.

Taxonomic order	Insect species	Station 1	Station 2	Station 3	Total
Odonata	*Aeshna* sp.	2	2	2	6
	Libellula sp.	2	3	6	11
	Gomphus sp.	13	9	7	29
Coleoptera	*Dysticus* sp.	4	2	1	7
	Hydrophilus sp.	7	7	5	19
	Stenelmis sp.	1	1	0	2
Hemiptera	*Ambrysus amargosus*	4	5	4	13
	Gerris lacustris	2	3	3	8
Plecoptera	*Neoperla spio*	5	3	1	9
Ephemeroptera	*Baetis* sp.	51	19	29	99
	Carnis horaria	2	3	0	5
	Cloeon dipterum	19	7	3	33
	Centroptilum sp.	20	7	7	34
Diptera	*Chironomus* sp.	14	4	11	29
No. of individuals (*n*)		146	75	79	300
No. of species (*n*)		14	14	12	40

The Ephemeroptera was the largest and the most dominant order including 55.33% species, followed by the Odonata (15.33%), Coleoptera (9.67%) and Diptera (9.67%), Hemiptera (7.00%) and Plecoptera (3%). The order Ephemeroptera recorded the highest density and was characterized by 4 families. Baetidae

Table 1

Physicochemical parameters of the sampling stations in Ethiope River from May to October 2014 (minimum and maximum values in parenthesis).

Parameters	Station 1	Station 2	Station 3	*F*-ANOVA months	*F*-ANOVA stations	*P*-months	*P*-stations
Water temperature (℃)	27.03 ± 2.27 (21–34)	27.05 ± 2.37 (20.00–34.00)	26.17 ± 2.37 (21.00–33.00)	95.70	1.53	< 0.05	> 0.05
Depth (m)	0.98 ± 0.09 (0.72–1.32)	1.00 ± 0.07 (0.74–1.25)	0.88 ± 0.07 (0.68–1.15)	82.60	0.27	< 0.05	> 0.05
pH	5.94 ± 0.21 (5.32–6.80)	5.76 ± 0.31 (5.20–7.20)	5.57 ± 0.18 (5.12–6.20)	0.83	0.20	> 0.05	> 0.05
DO (mg/L)	6.17 ± 0.51 (5.20–7.78)	6.14 ± 0.50 (6.60–6.89)	6.13 ± 0.06 (4.91–7.90)	4.63	0.00	< 0.05	> 0.05
BOD_5 (mg/L)	2.36 ± 0.17 (2.00–2.98)	2.43 ± 0.17 (2.05–3.00)	2.44 ± 0.16 (2.12–3.01)	0.51	0.01	> 0.05	> 0.05
Phosphate (mg/L)	0.01 ± 0.00 (0.01–0.02)	0.04 ± 0.00 (0.03–05)	0.012 ± 0.000 (0.01–0.02)	0.00	0.00	> 0.05	> 0.05
Nitrate (mg/L)	0.30 ± 0.07 (0.14–0.59)	0.12 ± 0.60 (0.01–0.00)	0.28 ± 0.08 (0.10–0.59)	0.11	0.00	> 0.05	> 0.05
Alkalinity (mg/L, $CaCO_3$)	1.08 ± 0.06 (0.80–1.24)	0.98 ± 0.08 (0.80–1.30)	1.25 ± 0.10 (0.80–1.50)	0.10	0.10	> 0.05	> 0.05
Sulphate (mg/L)	13.71 ± 0.07 (13.57–13.90)	2.92 ± 0.07 (0.28–3.13)	2.42 ± 0.03 (2.38–2.50)	0.03	162.80	> 0.05	< 0.05
Calcium (mg/L)	6.38 ± 0.01 (6.36–6.41)	6.39 ± 0.01 (6.35–6.41)	5.06 ± 0.02 (5.02–5.12)	0.00	2.36	> 0.05	> 0.05
Conductivity (μs/cm)	12.01 ± 2.98 (6.11–24.40)	9.63 ± 1.94 (5.26–15.00)	8.92 ± 1.89 (4.70–14.50)	89.38	15.73	< 0.05	< 0.05
Iron (mg/L)	0.25 ± 0.02 (0.21–0.29)	0.18 ± 0.01 (0.16–0.20)	0.18±0.07 (0.61–0.19)	0.00	0.01	> 0.05	> 0.05

contributed more than 50.0% of the total Ephemeroptera density. They were found in higher density in all the stations, but Station 1 recorded the highest density. The Odonata was represented by 3 families and taxa respectively. The families Gomphidae, Libellulidae and Aeshnidae were represented by *Gomphus*, *Libellula* and *Aeshna* species respectively. Of Coleoptera, *Dysticus* and *Hydrophilus* were found in all stations except *Stenelmis* species which was restricted to only Stations 1 and 2. The Hemiptera was represented by two families comprising *Ambrysus amargosus* and *Gerris lacustris* recorded in all stations. Plecoptera represented by *Neoperla spio* was present in all 3 stations with Station 1 recording the highest density. Diptera was represented by *Chironomus* species which was found in Stations 1, 2 and 3. The highest density of Diptera was recorded in Station 1 (Table 2).

The distribution of aquatic insect in the stations is shown in Figure 2. Station 1 had the highest number of individuals [146 (48.66%) individuals/m^2] represented by 14 taxonomic species followed by Station 3 [79 (26.34%) individuals/m^2] comprising 12 species. Station 2 had the lowest number of individuals [75 (25%) individuals/m^2] with 14 species (Table 3). Results revealed a significant difference ($P < 0.05$) between species. The presence of different taxa was also significantly different ($P < 0.05$) between the three sampling stations.
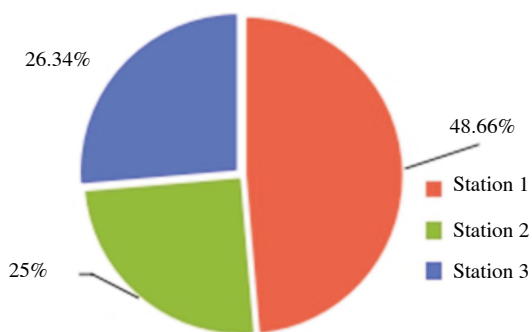

Figure 2. Percentage composition of aquatic insect in the study locations of Ethiope River.

Table 3
Distribution of major insect groups in the study site.

Taxa	Station 1	Station 2	Station 3
Odonata	17	14	15
Coleopteran	13	10	6
Hemiptera	6	8	7
Plecoptera	5	3	1
Ephemeroptera	91	36	39
Diptera	14	4	11
Total	146	75	79

The monthly species composition, abundance and distribution of aquatic insects in the sampling stations are presented in Table 4. The month of May had the highest species abundance/

density of 123 organisms/m^2 while September recorded the lowest density of 28 organisms/m^2. The Ephemeroptera and the Odonata had the highest density during the period of study. Spearman's rho correlation (r^2) showed that there was no significant correlation between water depth, pH, DO, BOD$_5$, alkalinity, nitrate, phosphorus, iron and aquatic insects in the sampling stations. While correlation was significant between water temperature, conductivity, sulphate and calcium and insect species with correlation (r^2) values being 0.557, 0.767, 0.656 and 0.749 respectively.

Table 4
Monthly species composition and distribution of aquatic insects.

Taxa	May	June	July	August	September	October
Odonata						
Aeshna sp.	0	1	2	1	1	2
Libellula sp.	5	5	0	0	0	1
Gomphus sp.	14	3	4	3	2	3
Coleoptera						
Dysticus sp.	4	2	1	0	1	0
Hydrophilus sp.	4	6	5	0	1	3
Stenelmis sp.	0	0	0	0	0	3
Hemiptera						
Ambrysus amargosus	0	0	2	4	3	4
Gerris lacustris	3	3	0	0	0	0
Plecoptera						
Neoperla spio	0	0	2	3	3	1
Ephemeroptera						
Baetis sp.	56	11	14	5	8	5
Caenis horiaria	0	1	2	0	0	2
Cloeon dipterum	11	3	2	8	4	1
Centroptilum sp.	11	10	5	2	2	3
Diptera						
Chironomus sp.	15	4	0	3	3	3
Total	123	50	39	29	28	31

Table 5 shows the monthly variation of insect density in the sampling stations from May to October, 2014. In the month of May, Station 1 had the highest number (63 of 146 individuals/m^2) of aquatic insects, closely followed by Stations 3 and 2. There was significant ($P < 0.05$) difference in the aquatic insect density in the study.

Table 5
Monthly variation in the abundance of aquatic insect in the stations.

Month	Station 1	Station 2	Station 3
May	63	20	39
June	20	20	11
July	17	12	10
August	15	10	6
September	17	6	6
October	14	7	7
Total	146	75	79

3.3. Taxa richness, diversity and dominance indices of aquatic insects in Ethiope River

Stations 1 and 2 had the taxa richness of 14 taxa with the

Margalef's index of 2.608 6 and 3.011 0 respectively. Station 3 had the minimum taxa richness of 12 taxa and Margelef's index of 2.517 5. Station 1 had the highest Simpson's dominance index of 0.174 9 followed by Station 3 with a dominance index of 0.173 6, and the lowest dominance index was found for Station 2 (Table 6).

Table 6
Diversity indices and composition density (individuals/m^2) of aquatic insects in Ethiope River.

Items	Station 1	Station 2	Station 3
No. of individuals	146.0000	75.0000	79.0000
No. of species/taxa	14.0000	14.0000	12.0000
Margalet's index (d)	2.6086	3.0110	2.5175
Shannon-Wiener index	0.9000	1.0300	0.8900
Evenness index (E)	0.7900	0.9000	0.8200
Simpson's Dominance Index (C)	0.1749	0.1000	0.1736
Simpson's index	5.7200	9.7400	5.7600

4. Discussion

The insect species collected from the upstream reaches of Ethiope River were assessed to determine the effects of hotel resort centres along the river. Insect fauna obtained in this study are different from those earlier reported in the river[10,16]. The water qualities, substrate/sediment and availability of nutrients (including zooplankton and phytoplankton) are important determinants of the abundance and distribution of aquatic insects[17]. The water qualities were the imperative factors for determining the ecology of these aquatic insects in this study. This assertion agrees with earlier studies of Arimoro *et al*.[18], Andrew and Arman[19], and Mohd *et al*.[7]. In their studies, they stated that weak correlation of aquatic invertebrates to water temperature could be attributed to physiological adaptation to anoxic conditions fashioned by high temperatures that reduce oxygen dissolution. It is important to note that *Chironomus* possesses haemoglobin for trapping dissolved oxygen.

Statistically, the physiochemical parameters (water temperature/depth, nitrate, alkalinity, pH, DO, BOD, phosphate, calcium and iron) of Ethiope River were not significantly different ($P > 0.05$) among the stations investigated (Table 1) while concentration of sulphate and conductivity differred significantly ($P < 0.05$). This current study showed a progressive increase of BOD$_5$ from Station 1 to Station 2 and the variation was not significantly different ($P > 0.05$) between the stations and months.

All stations were dominated by the Ephemeroptera particularly *Baetis* sp., *Centrotilum* sp. and *Caenis* sp. This observation was similar to study of Ikomi and Arimoro[10] in Ethiope River and other studies in Nigeria[16] and other areas[20,21]. The abundance of *Chironomus* species observed in Station 1 is likely due to the less flow velocity in this station. This assertion has been corroborated by Ikomi and Arimoro[10] who recounted that chironomid abundance is positively and negatively correlated

to organic matter and flow velocity respectively. The influence of dissolved oxygen on the distribution and diversity of aquatic insects was well corroborated in this study. Diversity was greater in Station 1 which had the highest DO level (6.17 mg/L). The high DO values (ranging from 5.20–7.78 mg/L) observed in Station 1 were attributed to large surface area, atmospheric air, sunlight as well as the abundance of organic debris which favoured the photosynthetic activities of aquatic plants. This observation was similar to earlier reports by Arimoro *et al*.[16]. The significant role of temperature in determining the solubility of oxygen which in turn affects species diversity cannot be over emphasized. Variation in water temperature is primarily governed by atmospheric temperature[22]. The low water temperature (26.17 ℃) recorded in Station 3 could be attributed to the shade provided by tree canopies resulting in the high abundance of Ephemeroptera recorded in this station. This temperature variation may be the plausible reason for the differences noticed in the dissolved oxygen levels in this study. This study showed that no significant difference ($P > 0.05$) was observed in water temperature between stations and within months. Biochemical oxygen demand, alkalinity, and nitrate concentration were significantly correlated with species density. Nutrient input into the river systems enhances the proliferation of aquatic insects as reflected in the increase of aquatic insects composition. Zalewski *et al*.[23] documented that nutrient increase in aquatic ecosystem increases secondary productivity, especially in reaches of river and streams with open canopy. Fourteen taxa comprising 300 individuals were collected (Table 2). The order Odonata was dominated by *Aeshna* sp., *Libellula* sp. and *Gomphus* sp. while Ephemeroptera was dominated by *Baetis* species, *Caenis horiaria*, *Cloeon dipterum* and *Centroptilum* sp. which were the most abundant species contributing about 57% of the total aquatic insects. The Ephemeroptera was the largest and the most dominant order accounting from 55.33% species.

The relatively high species richness and dispersal of sensitive aquatic insects are a reflection of the fair clean conditions of Ethiope River. This was further justified by a Margalef's index (d) of 2.608 6 and 2.517 5 for Stations 1 and 3 respectively. Station 2 had a Margalef's index of 3.011 0 further providing the evidence that it is minimally polluted than Stations 1 and 3. This is an indication that this site (Station 2) situated between the university hostel and Rivotel resort centre was insignificantly influenced by anthropogenic discharge even though it had the least (25%) species abundance. There are limited researches on the life histories, ecology and the potential role of aquatic insects in biological monitoring of water quality in lower Niger Delta area. It is necessary to strictly adhere to environmental/conservation laws guiding waste and effluent discharge into aquatic system such as Ethiope River which is known for recreational activities.

This study shows a momentous relationship between water quality and the presence of specific insect species, mainly *Neoperla spio*, *Caenis horiaria*, *Baetis* and *Chironomus*. The relatively strong

correlation of some aquatic insects to water quality is ascribed to their physiological adaptations to pollutions in Ethiope River. Distribution of organic matter, macrophyte cover, and waste from resort centres were responsible for the variations in species distribution, composition, abundance and taxonomic richness. Therefore, significant changes observed in aquatic insect composition were primarily due to changes in physicochemical parameter of water quality as a result of discharges from the resort centres. Aquatic insects have been proved to be good bio-indicator of pollution and their long-term monitoring is necessary for water quality evaluation in Ethiope River. This study is thus very useful in the conservation and management of waterways in Nigeria.

Conflict of interest statement

We declare that we have no conflict of interest.

References

[1] Arimoro FO, Ikomi RB. Ecological integrity of upper Warri River, Niger Delta using aquatic insects as bioindicators. *Ecol Indic* 2009; **9**: 455-61.

[2] Ito EE. Survey of parasites of two fish species (*Tilapia zillii* and *Clarias gariepinus*) in Ase River Catchment, Delta State, Nigeria. *J Coastal Life Med* 2017; **5**(10): 417-21.

[3] Kubendran T, Ramesh M. Composition and distribution of aquatic insect communities in relation to water quality in two freshwater streams of southern western ghats, India. *J Entomol Zool Stud* 2016; **4**(5): 689-95.

[4] Ummul F, Tri A, Windra P. Comparison of aquatic insect assemblages between managed and unmanaged artificial lakes in Indonesia. *J Entomol Zool Stud* 2017; **5**(2): 496-506.

[5] Deusiano FR, Ayala ES, Mayana MDM, Sheyla RMC, Paula BDM. Measurement of the ecological integrity of cerrado streams using biological metrics and the index of habitat integrity. *Insects* 2017; **8**(10): 1-15.

[6] Wahizatul AA, Hoon AG. Aquatic insect communities in relation with water quality of selected tributaries of Tasik Kenyir Terengganu. *J Sustainab Sci Mgt* 2016; **11**(2): 11-20.

[7] Mohd SS, Andrew BHW, Sahana H, Arman HF. The use of aquatic insects as bio-indicator to monitor freshwater stream health of Liwagu River, Sabah, Malaysia. *J Entomol Zool Stud* 2017; **5**(4): 1662-6.

[8] Majumder J, Das RK, Majumder P, Ghosh D, Agarwala BK. Aquatic insect fauna and diversity in Urban Fresh Water Lakes of Tripura. Northest India. *Mid East J Sci Res* 2013; **13**(1): 25-32.

[9] American Public Health Association. *Standard methods for the examination of water and waste water*. 22nd ed. Washington DC: APHA Press; 2012.

[10] Ikomi RB, Arimoro FO. Effects of recreational activities on the littoral macroinvertebrates of Ethiope River, Niger Delta, Nigeria. *J Aquat Sci* 2014; **29**(1B): 155-70.

[11] Cranston PS. Electronic guide to the Chironomidae of Australia. Broadway: University of Technology Sydney; 2000. [Online] Available from: http://www.science.uts.edu.au/sasb/chiropage/ [Accessed on 11th September, 2012]

[12] Gerber A, Gabriel MJM. *Aquatic invertebrates of South African rivers. Field guide*. Volume I and II. Pretoria: Institute for Water Quality Studies; 2002.

[13] Pennak RW. *Freshwater invertebrates of the United States*. 2nd ed. New York: John Wiley and Sons, Inc.; 1978.

[14] Ogbeibu AE. *Biostatistical: a practical approach to research and data handling*. Benin City: Mindex Publishing Co Ltd; 2005.

[15] Magurran A. *Ecological diversity and its measurements*. Dordrecht: Springer; 1988, p. 24-76.

[16] Arimoro FO, Nwadukwe FO, Mordi KI. The influence of habitat and environmental water quality on the structure and composition of adult aquatic insect fauna of Ethiope River, Delta state, Nigeria. *Trop Zool* 2011; **24**: 159-71.

[17] Prommi T, Payakka A. Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. *Sains Malaysiana* 2015; **44**(5): 707-17.

[18] Arimoro FO, Ikomi RB, Iwegbue CMA. Water quality changes in relation to Diptera community patterns and diversity measured at an organic effluent impacted stream in the Niger Delta, Nigeria. *Ecol Indic* 2007; **7**: 541-52.

[19] Andrew BHW, Arman HF. Aquatic insect communities in and around the tropical streams of Kinabalu Park, Sabah, Malaysia. *Bioflux* 2016; **9**(5): 1078-89.

[20] Gogoi A, Gupta S. Aquatic insect community of River Brahmaputra near Dibru Saikhowa National Park, Assam, North East India. *J Entomol Zool Stud* 2017; **5**(2): 1257-65.

[21] Nelson SM, Liebermann DM. The influence of flow and other environmental factors on the benthic invertebrates in Sacramento River, USA. *Hydrobiologia* 2002; **489**(1): 117-29.

[22] Barman B, Gupta S. Aquatic insects as bio-indicator of water quality-a study on Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India. *J Entomol Zool Stud* 2015; **3**(3): 178-86.

[23] Zalewski M, Bis B, Lapinska M, Franklewitcz P, Puchalsky W. The importance of the riparian ecotone and river hydraulics for sustainable basin-scale restoration scenarios. *Aquat Conserv Mar Freshwater Ecosyst* 1998; **8**: 287-307.