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ASSESSMENT OF MACROINVERTEBRATE COMMUNITY IN A RURAL NIGERIAN RIVER IN RELATION TO ANTHROPOGENIC ACTIVITIES

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Abstract

An assessment of macroinvertebrate community and water quality of a rural river in South-East Nigeria was carried out between May and October 2019 in three stations in relation to anthropogenic activities. The major anthropogenic activity in the river was indiscriminate sand mining. The water samples were collected and analyzed using standard methods while macroinvertebrates were sampled using modified kick method and sweeping of aquatic macrophytes with handnet. Results showed that pH, dissolved oxygen and biochemical oxygen demand were not within acceptable limits. 346 macroinvertebrates individuals from 12 taxa and 3 taxonomic groups were recorded. The macroinvertebrates consist more of pollution tolerant species like *Haliplus* sp. larvae and *Chironomus* sp. larvae and the community structure pointed to perturbation. Canonical correspondence analysis showed that the first canonical axis accounted for over 80% of the variation with eigen value of 0.042. Axis 1 had strong positive association with Hemiptera and Diptera explained by temperature and BOD while Axis 2 had strong positive association with Araneae influenced by phosphate and BOD. Station 2 influenced by temperature, had strong positive association with Axis 1 while station 1 influenced by pH, TDS and EC, had strong negative association with Axis 1. Station 3 influenced by phosphate and BOD had strong positive association with Axis 2. Indiscriminate sand mining have not adversely affected the water quality; however, the macroinvertebrate community was adversely affected which reflected in the dominance of tolerant species and the community structure.

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Introduction

Rivers as important biodiversity systems are among the most productive ecosystems on the earth and provide the favourable conditions that support wide range of flora and fauna. Most of the freshwater bodies all over the world are polluted as a result of human activities and thus affecting the ecosystem services derivable from them (GUPTA et al. 2005, ANYANWU 2012, GOLDSCHMIDT 2016, AMAH-JERRY et al. 2017). The quality of water can be affected by meteorological and climatic factors while the variability of anthropogenic activities was the major factor that could explain the day to day variability (SCHEILI et al. 2016a, b). Indiscriminate sand mining is a major anthropogenic activity in most rivers in the region (including Iyiakwu River), which was observed to increase with increasing rainfall (ANYANWU and UMEHAM 2020). Indiscriminate sand mining has been reported as one of the potential threats to the freshwater biota; through increased turbidity, reduced organic detritus supply, loss of breeding and spawning grounds (SHEEBA 2009). The quality of the aquatic ecosystem can be predicted by the assessment of biological communities and many researchers have used this approach to determine the ecological effects of pollution (AKINDELE and LIADI 2014, ANYANWU et al. 2019, ALIU et al. 2020, SANTOS and FERREIRA 2020). The Nigerian inland waters have been reported to support a wide range of aquatic organisms (ATOBATELE and UGWUMBA 2008).

The freshwater macroinvertebrates are largely made up of insects; others include crustaceans, gastropods, bivalves and oligochaetes (ALLAN 1995, MERRITT et al. 2008, THORP and COVICH 2001). The use of macroinvertebrates in biological monitoring have been consistent and reliable when compared to the use of other organisms (plankton, fish, etc) because they have wide distribution, sensitive to organic pollutants and easy to sample at minimal cost (KALYONCU and GULBOY 2009, SETIAWAN 2009). Factors like water quality, substrate type, sediment and particle size, flow regime determine the community structure of macroinvertebrates in association with the prevailing conditions in the watershed (WARD et al. 1995, BUSS et al. 2004).

A number of studies on macroinvertebrate communities and water quality have been carried out in Nigeria (ARIMORO et al. 2015, ANYANWU and JERRY 2017, IYAGBAYE et al. 2017, ANYANWU et al. 2019, ALIU et al. 2020). However, little attention has been given to the best of my knowledge to smaller rural rivers like Iyiakwu, scattered all over the country and harbour a significant proportion of the nation's freshwater biodiversity.

The objective of this study was to assess the macroinvertebrate community and water quality of Iyiakwu River, Elemaga, Ikwuano, South-East Nigeria in relation to anthropogenic activities.

Materials and Methods

Study area and sampling stations

The study was carried out in Iyiakwu River, Elemaga, Ikwuano Local Government Area, Abia State, Nigeria. The section of the river studied lies within Latitude 05°26’21”–05°26’40”N and Longitude 07°37’3”–07°37’16”E (Figure 1). The study area is within the sub-equatorial zone; having a mean annual rainfall of 4000 mm (Nwankwo and Nwankwoala 2018). It is characterized by high relative humidity of over 70% and high temperature of about 29–31°C (Nwankwo and Nwankwoala 2018). It is also characterized by the wet season (May to October) and dry season (November to April); a double maxima rainfall peaks in July and October. The area also experiences a short period of dryness between the peaks in August usually referred to as “August break”.

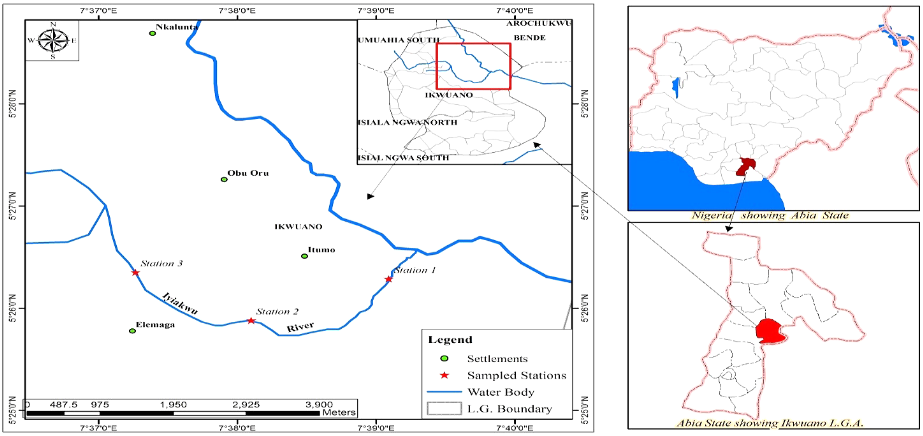


Fig. 1. Map of Elemaga, Ikwuano LGA, Abia State, Nigeria showing the sampling stations of Iyiakwu River

Uhegbu et al. (2013) reported that the area is situated geologically in the Eastern Niger Delta; falling within Bende-Ameki Formation and the Benin Formation in Abia State. The Bende-Ameki formation was further classified into two lithological groups – the lower part made up of fine to coarse grain sandstones and intercalations of calcareous shales and thin shelly limestone and upper part made up of coarse, cross-bedded sandstone with bands of fine, grey-green sandstone and sandy fossiliferous clays (FMEnv. 2005). The age of the formation has been reported to be early Eocene and early middle Eocene respectively (Uhegbu et al. 2013, Obasi et al. 2015). The area is endowed with natural springs and streams including Iyiakwu River which flows from Bende (the northern boundary) through the study area in a south-westerly direction and empties itself at the Qua Iboe river in Akwa Ibom state (UKAGWU et al. 2017, NWANKWO and NWANKWOALA 2018)

Station 1 was upstream, located in an agricultural area with sandy substrate. Sand mining activities were observed some distances upstream of this station. Human activities observed during the study include extraction of water for drinking, processing of breadfruit (*Treculia africana*) and fermentation of cassava (*Manihot esculenta*) tubers in plastic containers and farming activities. Station 2 was 2.15 km downstream of station 1 with sandy substrate. Sand mining activities was intense; other activities include extraction of water for drinking and nursery, washing of clothes, fermentation and processing of cassava (*Manihot esculenta*) tubers in plastic containers and swimming. Station 3 was 1.97 km downstream of station 2; also with sandy substrate. It was located within a large expanse of palm bush, cocoa farms and farmlands. Little or no activities were observed during the study but sand mining activities was observed in September and October 2019.

Samples Collection and Analyses

Water samples

Water samples were collected monthly from Iyiakwu River between May and October 2019 in sterilized 1litre plastic bottles. Some physicochemical parameters were determined *in-situ* – water temperature was determined with mercury-in-glass thermometer, flow velocity was determined by floatation method, transparency was determined with Secchi Disk, pH, electrical conductivity and total dissolved solids were all determined with handheld meter (pH/EC/TDS Meter-HANNA 3100 Model). Other parameters were determined in the laboratory – dissolved oxygen and biochemical oxygen demand were determined with Winkler's Method with azide modification method while nitrate was determined with UV spectrophotometric method and phosphate with stannous chloride method.

Macroinvertebrate sampling

Macroinvertebrate samples were collected from the sediments using the modified kick sampling technique described by KEÇI et al. (2012). The sediment upstream was disturbed by kicking with foot for about 5 minutes and the macroinvertebrates dislodged were washed into the net placed downstream of the disturbed point. Aquatic macrophytes along the banks of the river were also swept with the hand net against the water current and the macroinvertebrates dislodged were washed into the net. All the samples were preserved with 10% formalin in a plastic container and taken to the laboratory for proper identification. The isolated macroinvertebrates were identified to the lowest possible taxonomic level with the aids of the following taxonomic keys: WILLOUGHBY (1976), MERRITT and CUMMINS (1996) and UMAR et al. (2013). The numbers were counted.

Statistical Analysis

The data were summarised into maximum, minimum, mean and standard error of the mean using Descriptive Statistic Package of Microsoft Excel while two-way ANOVA was used to test for statistical differences among the stations and months. Tukey's pairwise comparisons test was performed to determine the location of significant difference ($P < 0.05$). The community structure of macroinvertebrates was determined using Margalef (D), Shannon-Wiener (H) and Evenness (E) indices. Canonical correspondence analysis (CCA) was used to evaluate relationships between the macroinvertebrate groups and environmental variables with PAST statistical package (HAMMER et al. 2001).

Results

Water quality

The summary of physico-chemical parameters measured in the surface water of Iyiakwu River is shown in Table 1. Two-way analysis variance (ANOVA) showed that there were no significant differences ($P > 0.05$) in all the physicochemical parameters evaluated.

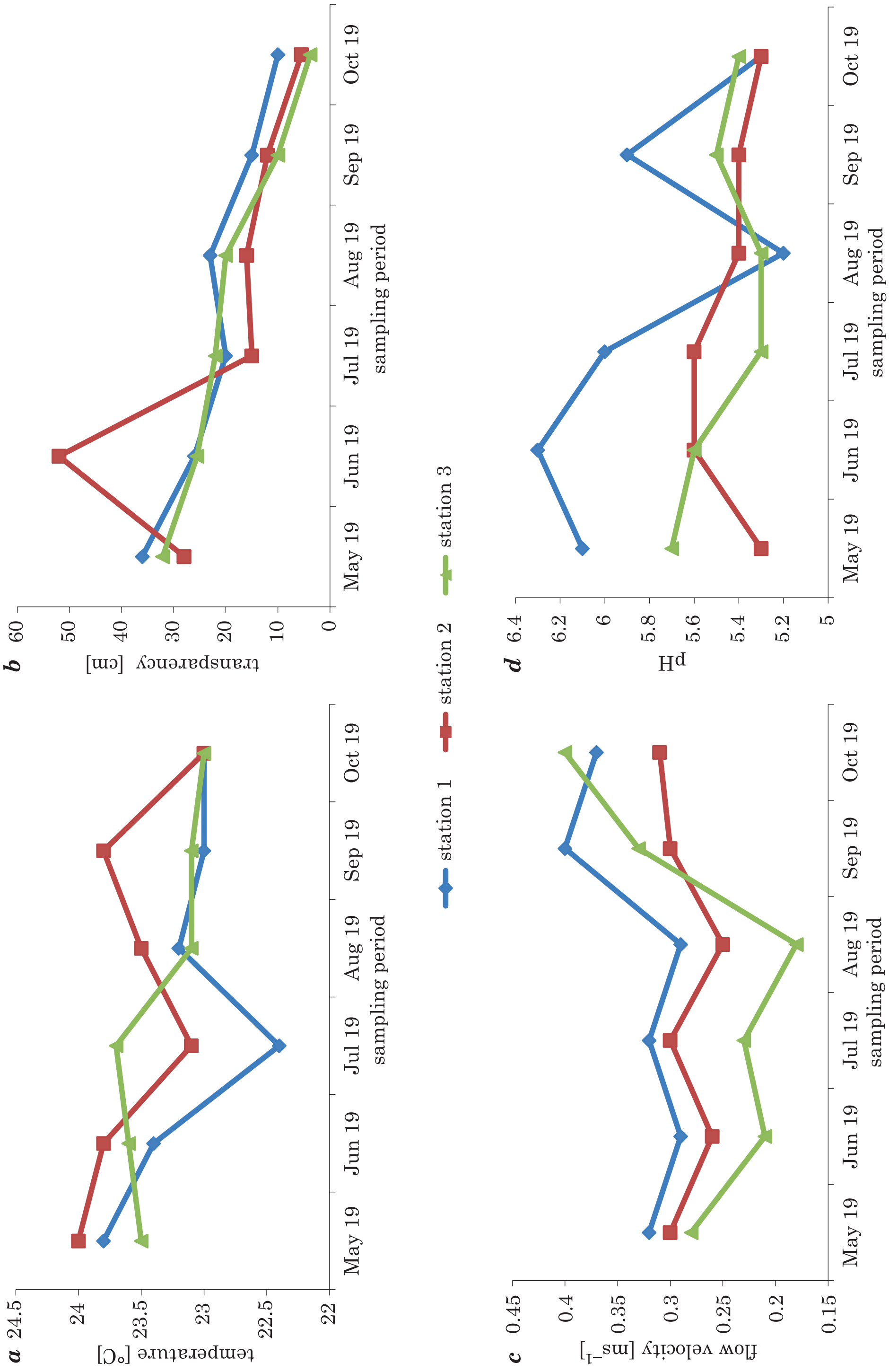
Water temperature values ranged between 22.4 and 24.0°C. The lowest water temperature value was recorded in station 1 in July 2019 while the highest water temperature value was recorded in station 2 in May 2019 (Figure 2*a*). The transparency values ranged between 3.8 and 52.0 cm. The lowest transparency value was recorded in station 3 in October 2019 while the highest transparency value was recorded in station 1 in June 2019 (Figure 2*b*). Transparency generally decreased with increasing rainfall from May to October 2019. The flow velocity values ranged between 0.18 and 0.40 ms^{-1}. The lowest flow velocity value was recorded in station 2 in August 2019 while the highest flow velocity value was recorded in station in 3 in September 2019 (Figure 2*c*). The flow velocity generally increased with the rains from August 2019.

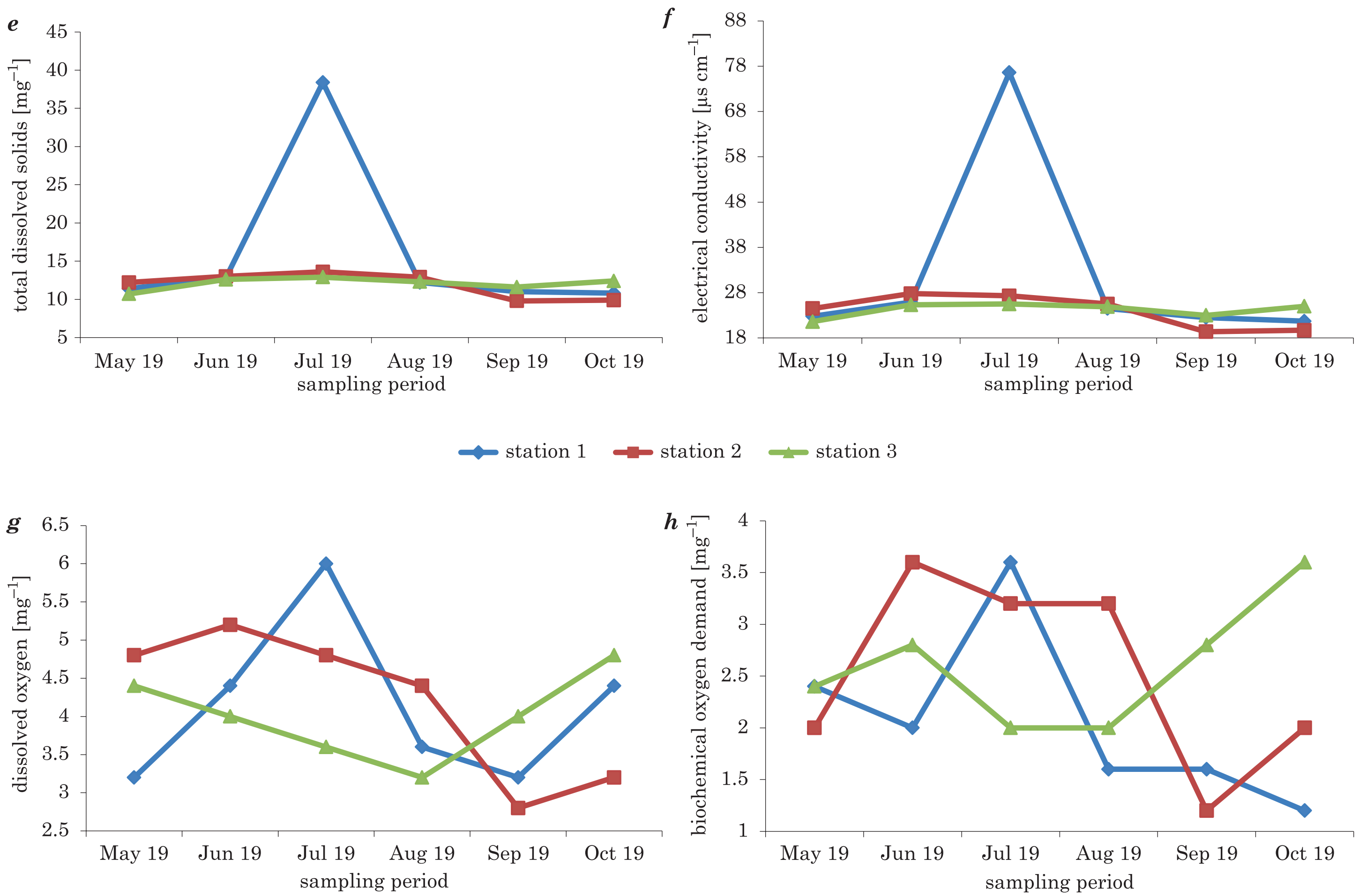
Table 1

Summary of some physico-chemical parameters of Iyiakwu River (with range in parenthesis)

Parameter	Station 1 X±SEM	Station 2 X±SEM	Station 3 X±SEM	Station P-value	Month P-value	FMEnv.
Water temperature [°C]	23.1±0.19 (22.4–23.8)	23.5±0.17 (23.0–24.0)	23.3±0.12 (23.0–23.7)	0.336	0.353	–
Transparency [cm]	21.7±3.69 (10.0–36.0)	21.4±6.80 (5.5–52.0)	18.9±4.22 (3.8–32.1)	0.637	0.073	–
Flow velocity [ms^{-1}]	0.33±0.02 (0.29–0.40)	(0.28±0.01) 0.25–0.31	(0.27±0.03) 0.18–0.40	0.590	0.155	–
pH	5.8±0.18 (5.2–6.3)	5.4±0.06 (5.3–5.6)	5.5±0.07 (5.3–5.7)	0.741	0.671	6.5–8.5
Total dissolved solids [$mg\ l^{-1}$]	16.1±4.47 (10.8–38.4)	11.9±0.67 (9.8–13.6)	12.1±0.32 (10.7–12.9)	0.788	0.291	–
Conductivity [$\mu S\ cm^{-1}$]	32.3±8.87 (21.7–76.6)	24.0±1.50 (19.4–27.8)	24.2±0.64 (21.6–25.5)	0.901	0.288	–
Dissolved oxygen [$mg\ l^{-1}$]	4.1±0.43 (3.2–6.0)	4.2±0.40 (2.8–5.2)	4.0±0.23 (3.2–4.8)	0.718	0.746	> 6
Biochemical oxygen demand [$mg\ l^{-1}$]	2.1±0.35 (1.2–3.6)	2.5±0.38 (1.2–3.6)	2.6±0.25 (2.0–3.6)	0.907	0.821	3
Nitrate [$mg\ l^{-1}$]	0.19±0.02 (0.15–0.31)	0.19±0.01 (0.14–0.24)	0.17±0.01 (0.12–0.21)	0.269	0.105	50
Phosphate [$mg\ l^{-1}$]	0.11±0.02 (0.09–0.20)	0.11±0.01 (0.08–0.15)	0.11±0.01 (0.09–0.13)	0.629	0.122	3.5

SEM – Standard Error of Mean; FMEnv. – Federal Ministry of Environment (2011)


a
temperature [°C]
24.5
24
23.5
23
22.5
22
May 19
Jun 19
Jul 19
Aug 19
Sep 19
Oct 19
sampling period
b
transparency [cm]
60
50
40
30
20
10
0
c
flow velocity [ms^{-1}]
0.45
0.4
0.35
0.3
0.25
0.2
0.15
d
pH
6.4
6.2
6
5.8
5.6
5.4
5.2
5
station 1
station 2
station 3


e
total dissolved solids [mg^{-1}]
45
40
35
30
25
20
15
10
5
May 19
Jun 19
Jul 19
Aug 19
Sep 19
Oct 19
sampling period
f
electrical conductivity [µs cm^{-1}]
88
78
68
58
48
38
28
18
May 19
Jun 19
Jul 19
Aug 19
Sep 19
Oct 19
sampling period
station 1
station 2
station 3
g
dissolved oxygen [mg^{-1}]
6.5
6
5.5
5
4.5
4
3.5
3
2.5
May 19
Jun 19
Jul 19
Aug 19
Sep 19
Oct 19
sampling period
h
biochemical oxygen demand [mg^{-1}]
4
3.5
3
2.5
2
1.5
1
May 19
Jun 19
Jul 19
Aug 19
Sep 19
Oct 19
sampling period

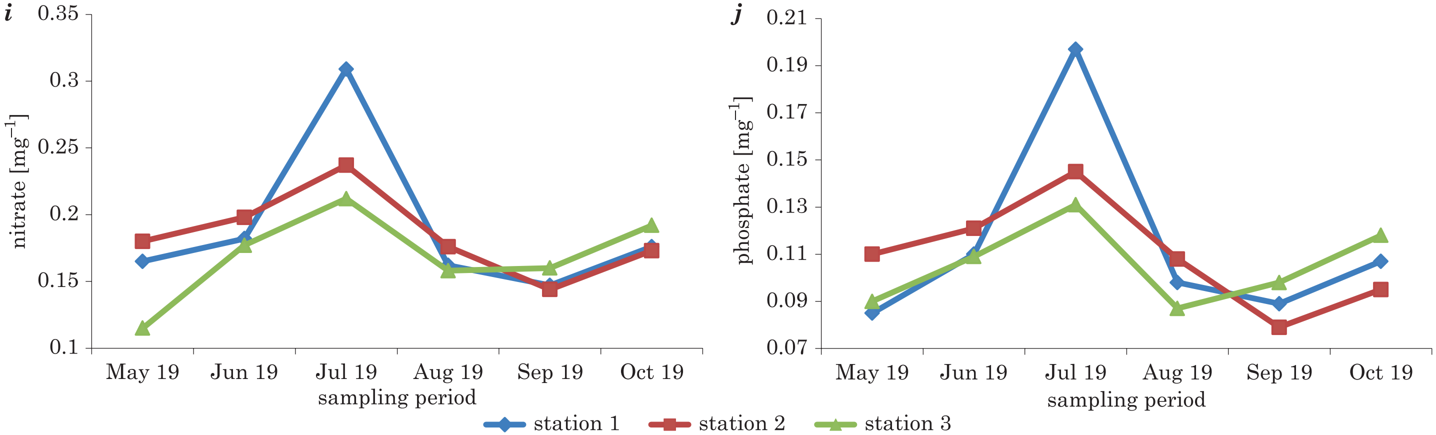


Fig. 2. Spatio-temporal variations of: *a* – temperature; *b* – transparency; *c* – flow velocity; *d* – pH; *e* – total dissolved solids; *f* – electrical conductivity; *g* – dissolved oxygen; *h* – biochemical oxygen demand; *i* – nitrate; *j* – phosphate in Iyiakwu River, South-East Nigeria in 2019

pH values ranged between 5.2 and 6.3. The lowest pH value was recorded in station 1 in August 2019 while the highest pH was recorded in station 1 in June 2019 (Figure 2*d*). All pH values were acidic and outside the acceptable limit set by FMEnv. (2011). Electrical conductivity values ranged between 19.4 and 76.6 μS cm^{-1}. The lowest conductivity value was recorded in station 3 in September 2019 while the highest conductivity value was recorded in station 1 in July 2019 (Figure 2*e*). Total dissolved solid values recorded ranged between 9.8 and 38.4 mg l^{-1}. The lowest TDS value was recorded in station 2 in September while the highest TDS value was recorded in station 1 in July 2019 (Figure 2*f*). TDS followed the same trend as Electrical Conductivity. Dissolved oxygen values ranged between 2.8 and 6.0 mg l^{-1}. The lowest DO value was recorded in station 3 in September 2019 while the highest DO value was recorded in station 2 in July 2019 (Figure 2*g*).

All DO values were lower than acceptable limit, except one in station 1 (July 2019). Biochemical Oxygen Demand values ranged between 1.2 and 3.6 mg l^{-1}. The lowest BOD value was recorded in station 1 in September 2019 while the highest BOD values were recorded in stations 1, 2 and 3 in July, June and October 2019 respectively (Figure 2*h*). These values exceeded limit set by FMEnv. (2011).

Nitrate values ranged between 0.12 and 0.31 mg l^{-1}. The lowest nitrate value was recorded in station 3 in May 2019 while the highest nitrate value was recorded in station 1 in July 2019 (Fig. 2*i*). Station 1 was generally higher than the others though within acceptable limit. The phosphate values ranged between 0.08 and 0.20 mg l^{-1}. The lowest phosphate value was recorded in station 2 in September 2019 while the highest phosphate value was recorded in station 1 in July 2019 (Figure 2*j*). All the phosphate values were within acceptable though station 1 recorded higher values.

Macroinvertebrates Composition, Abundance and Distribution

The overall species composition, abundance and distribution of macroinvertebrates are presented in Table 2. A total of 346 macroinvertebrate individuals comprising of three (3) taxonomic groups and twelve (12) taxa was recorded. Percentage composition of the taxa showed that freshwater shrimp, *Caridina africana* had the highest abundance (24%), followed by crawling water beetle, *Haliplus* sp. larvae (16.8%) while the least was the water strider (*Aquarius remigis*). All the macroinvertebrates recorded in this study were tolerant species except *Caridina africana.*

Spatially, station 3 recorded the highest number of macroinvertebrate individuals (127), followed by station 1 (116 individuals) and the least is station 2 (103 individuals). Monthly, the highest number of individuals

(31) was recorded in May and June 2019 while the lowest (3 individuals) was recorded in October 2019 (station 1). In station 2, the highest number of individuals (35) was recorded in May 2019 while the lowest (4 individuals) was recorded in October 2019. The highest number of individuals recorded in station 3 was 29 in July 2019 while the lowest (5 individuals) was also in October 2019 (Figure 3).

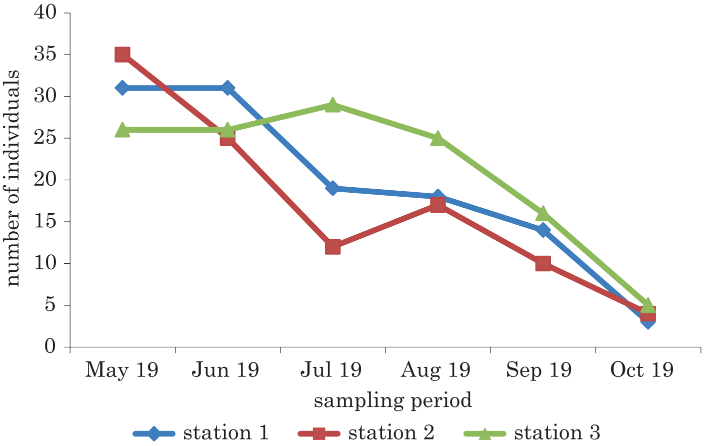


Fig. 3. Monthly distribution of macroinvertebrate individuals in Iyiakwu River, South-East Nigeria

Table 2

Species composition, abundance and distribution of macroinvertebrate fauna encountered in Iyiakwu River, Elemaga, Southeast Nigeria

Group	Taxa	Stn 1	Stn 2	Stn 3	Total	Percentage
Insecta Hemiptera	*Aquarius remigis* (Say, 1832)	1	4	4	9	2.6
Diptera	*Chironomus* sp. (Meigen, 1803)	3	15	11	29	8.4
	Anopheles gambiae (Giles, 1902)	3	4	5	12	3.5
Coleoptera	*Haliplus* sp. *Larvae* (Stephens, 1821)	17	19	22	58	16.8
	Agabus bipustulatus (Linnaeus, 1767)	4	5	7	16	4.6
	Hydrophilis triangularis (Say, 1823)	10	5	9	24	6.9
Odonata	*Libellula* sp. nymph (Linnaeus, 1758)	10	6	8	24	6.9
	Gomphus sp. nymph (Charpentier, 1825)	9	7	8	24	6.9
	Macromia sp. nymph (Walsh, 1862)	8	9	6	23	6.7
Crustacea Decapoda	*Sudanonautes africanus* (A. Milne-Edwards, 1869)	9	8	10	27	7.8
	Caridina africana (H. Milne-Edwards, 1837)	37	18	28	83	24
Arachnida Araneae	*Argyroneta aquatica* (Clerck, 1758)	5	3	9	17	4.9

The community structure showed that Margalef species richness index had a narrow range of between 2.271 and 2.273 (Table 3). On the other hand, Shannon-Wiener index ranged from 2.131 to 2.313; with the highest value recorded in station 3. The highest Evenness index (0.8418) was also recorded in station 3.

Table 3

Biodiversity indices of macroinvertebrate fauna of Iyiakwu River, South-East Nigeria

Biodiversity indices	Stn 1	Stn 2	Stn 3
Taxa (S)	12	12	12
Individuals	116	103	127
Shannon-Wiener (*H*)	2.131	2.306	2.313
Evenness (E)	0.7021	0.8362	0.8418
Margalef (D)	2.314	2.373	2.271

Relationship between macroinvertebrate and physico-chemical parameters

The canonical correspondence analysis (CCA) ordination also showed a good relationship between the macroinvertebrate groups and environmental variables. The first canonical axis accounted for over 80% of the variation in the data set (Table 4). Axis 1 had strong positive association

Table 4

Correlations of environmental variables with the two axes of canonical correspondence analysis (CCA)

Variables	Axis 1	Axis 2
Eigenvalue	0.041576	0.009274
Variation of species data explained [%]	81.76	18.24
HEM	0.483973	0.065333
DIP	0.445396	-0.0415
ARA	-0.0433	0.352332
Station 1	-1.31265	-0.50962
Station 2	1.15547	-1.01371
Station 3	0.261842	1.28763
Temperature	0.987553	-0.20835
pH	-0.99243	-0.07109
TDS	-0.94815	-0.26817
EC	-0.94123	-0.28843
BOD	0.849489	0.482787
PO4	-0.35756	0.951195

with Hemiptera and Diptera; explained mostly by temperature and BOD while Axis 2 also had strong positive association with Araneae that was mostly explained by phosphate and BOD (Table 4, Figure 4). Spatially, Axis 1 had strong positive association with station 2; explained mostly by temperature and strong negative association with station 1; explained by pH, TDS and EC. On the other hand, Axis 2 had strong positive association with station 3 that was mostly explained by phosphate and BOD (Table 4, Figure 4).

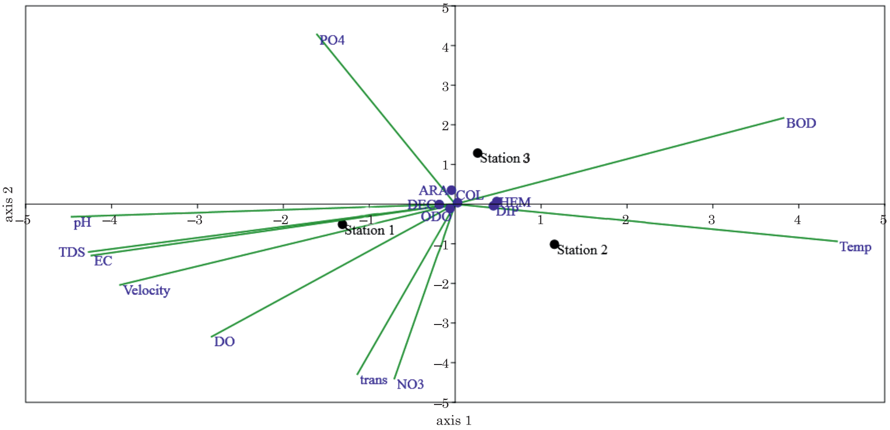


Fig. 4. Canonical correspondence analysis (CCA) ordination showing relationships between macroinvertebrate groups, sites and environmental variables (BOD – biochemical oxygen demand, DO – dissolved oxygen; trans – transparency; temp – water temperature; NO_3 – nitrates; PO_4 – phosphates; EC – electrical conductivity; Ara – araneae; Col – coleoptera; Hem – hemiptera; Dec – decapoda; Odo – Odonata; Dip – diptera)

Discussion

Water quality

All the water temperature values were low though station 2 recorded slightly higher temperatures which could be attributed to the openness of the station; the other stations were shaded by trees. According to Mohseni and Stefan (1999) and Webb et al. (2003), air temperatures influence water temperatures; the lowest water temperature was recorded in station 1 in July, which is one of the peaks of wet season while the highest value was recorded in station 2 in May before the onset of the wet season. The temperatures values recorded in this study were relatively lower compared to values recorded elsewhere in Nigeria. Abdullahi et al. (2008) recorded 27.7–29.9°C in Challawa River, Kano, Akpe et al. (2018) recorded 23.0–30.5°C in Ikpoba River, Benin City and Anyanwu and Mbekee (2020) recorded 21.0–28.0°C in Ossah River, Umuahia, Nigeria.

The lowest transparency was recorded in station 3 in October; attributable to season and mining activities which peaked in September and October 2019 while the highest was recorded in station 1 before the early rains in June 2019. Anthropogenic activities like sand mining reduce transparency and light penetration (KALE 2016) and have adverse effect on benthic community and other aquatic organisms (ESENOWO and UGWUMBA 2010). The transparency values were low compared to 12.5–100 cm recorded by ANYANWU (2012) in Ogba River, Benin City and 50.0–94.0 cm recorded by ANYANWU and MBEKEE (2020) in Ossah River, Umuahia, Nigeria.

The flow velocities were moderate and generally increased with the rains. The lowest value was recorded in station 2 during the August break while the highest values were recorded in stations 1 and 3 during the peaks of rain (September and October 2019 respectively). The flow velocities were lower than 1.48–1.83 ms^{-1} recorded in selected river in Ebonyi State, South-East Nigeria by ANI et al. (2016) but higher than 0.05–0.13 ms^{-1} recorded by ANYANWU and MBEKEE (2020) in Ossah River, Umuahia, Nigeria. Different taxa are known to cope with different flow velocity thresholds and time spans of being exposed to increased discharge (BROOKS et al. 2005, OLDMEADOW et al. 2010). The velocity of water body also influences the water body ability to assimilate and remove water pollutants (EFFENDI et al. 2015).

The pH values were acidic and not within acceptable limit; attributed to the geogenic, seasonal and anthropogenic influences. The values were within the range recorded in the related studies in the region. ANYANWU et al. (2019) recorded a range of 4.6–6.3 in Ossah River, Umuahia and ANYANWU and UMEHAM (2020) recorded a range of 4.9–6.3 in Eme River, Umuahia, Nigeria. However, AMAH-JERRY et al. (2017) recorded a higher range of 5.0–9.1 in Aba River, Aba. The lowest value was recorded in station 1 during the August break attributed to low precipitation and higher atmospheric temperatures leading to concentration while the highest value recorded in station 1 during the onset of rains in June may be due to dilution by rain water (ATOBATELE and OLUTONA 2013, ETESIN et al. 2013, HOUSSOU et al. 2017). Sand mining activities also reduce the pH level of water bodies as observed in ANYANWU et al. (2019) and ANYANWU and UMEHAM (2020). Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent (MANICKAM et al. 2015).

The electrical conductivity values were moderate. Related studies in the region recorded close ranges. AMAH-JERRY et al. (2017) recorded a range of 3.5–98.0 $\mu S\ cm^{-1}$ in Aba River, Aba and ANYANWU et al. (2019) recorded a range of 52.9–110.5 $\mu S\ cm^{-1}$ in Ossah River, Umuahia, Nigeria.

The lowest value was recorded in station 3 in September 2019 which could be attributed to dilution by increased rainfall while the highest was recorded in station 1 in July which could be attributed to intense sand mining activities around the station. The highest value recorded in ANYANWU et al. (2019) was in station 1 that was subjected to sand mining activities. REHMAN et al. (2016) and AKANKALI et al. (2017) reported that sand mining activities can contribute to the increase in EC values while DORAK (2013) pointed out that increasing EC is an indication of increasing pollution

Total Dissolved Solids values were within acceptable limits and followed the same trend with Electrical conductivity. AMAH-JERRY et al. (2017) recorded a range of 8.0–24.2 mg l^{-1} in Aba River, Aba and ANYANWU et al. (2019) recorded a range of 25.7–55.3 mg l^{-1} in Ossah River, Umuahia, Nigeria. EWA et al. (2011) reported that high level of EC usually correspond to high value of TDS. Sand mining activities can contribute to the increase in TDS as observed in electrical conductivity.

Most of the Dissolved Oxygen values were lower than acceptable limit. This trend was observed in related studies in the region. AMAH-JERRY et al. (2017) recorded a higher range of 2.7–8.8 mg l^{-1} in Aba River, Aba, ANYANWU et al. (2019) recorded a range of 3.2–6.4 mg l^{-1} in Ossah River, Umuahia and ANYANWU and UMEHAM (2020) recorded a range of 1.6–6.1 mg l^{-1} in Eme River, Umuahia, Nigeria. The lowest value was recorded in station 3 in September 2019 while the highest value was recorded in station 2 in July 2019. Some of the impacts associated with sand mining activities like addition of nutrients and chemicals, altering the flow of water and raising the water temperature can reduce the oxygen content of water (RAO et al. 2013). The lowest DO value recorded in ANYANWU and UMEHAM (2020) was in station 4, which was immediately downstream to active sand mining and sand landing sites.

Some BOD values were above the acceptable limit. This trend was observed in related studies in the region. AMAH-JERRY et al. (2017) recorded a higher range of 1.1–6.1 mg l^{-1} in Aba River, Aba, ANYANWU et al. (2019) recorded a range of 1.5–4.2 mg l^{-1} in Ossah River, Umuahia and ANYANWU and UMEHAM (2020) recorded a range of 0.8–4.3 mg l^{-1} in Eme River, Umuahia, Nigeria. Relatively higher values were recorded in stations 1, 2 and 3 in July, June and October 2019 respectively, which could be associated with sand mining activities. This agreed with AKANKALI et al. (2017), ANYANWU et al. (2019) and ANYANWU and UMEHAM (2020).

Nitrate values were all within acceptable limit. The values were lower than the range recorded in the related studies in the region. AMAH-JERRY et al. (2017) recorded a higher range of 7.4–79.8 mg l^{-1} in Aba River, Aba, ANY-

ANWU et al. (2019) recorded a range of 0.9–3.4 mg l^{-1} in Ossah River, Umuahia and ANYANWU and UMEHAM (2020) recorded a range of 1.1–5.6 mg l^{-1} in Eme River, Umuahia, Nigeria. The lowest value was recorded in station 3 before the onset of rains in May 2019 while the highest was recorded in station 1 during one of the peaks in July 2019. Station 1 was generally higher than the others though within acceptable limit, which could be attributed to the farming activities in the watershed rather than sand mining activities. SOLANKI (2012) reported that runoffs from agricultural fields is one of the major sources of nitrate inputs into freshwater. This is contrary to ANYANWU et al. (2019) and ANYANWU and UMEHAM (2020) where the highest values were recorded in stations subjected to sand mining activities.

All the phosphate values were within acceptable limit though station 1 recorded higher values. The values were lower than the range recorded in the related studies in the region. AMAH-JERRY et al. (2017) recorded a higher range of 2.3–79.8 mg l^{-1} in Aba River, Aba, ANYANWU et al. (2019) recorded a range of 0.1–2.7 mg l^{-1} in Ossah River, Umuahia and ANYANWU and UMEHAM (2020) recorded a range of 0.4–4.6 mg l^{-1} in Eme River, Umuahia, Nigeria. The lowest value was recorded in station 2 in September 2019; attributable to dilution while the highest was recorded in station 1 in July 2019; attributable to agricultural activities as in the case of nitrate. Use of fertilizers and pesticides are some of the sources of phosphate in water system (MANDEL et al. 2012). This is also contrary to ANYANWU et al. (2019) and ANYANWU and UMEHAM (2020) where the highest values were recorded in stations subjected to sand mining activities.

Macroinvertebrates

The macroinvertebrate species composition was dominated by group insecta as in ANYANWU et al. (2019) but different from the dominance of group mollusca in ANYANWU and JERRY (2017). The number of individuals was higher, taxonomic groups lower and taxa was higher when compared to 168 individuals, 4 taxonomic group and 7 taxa recorded by ANYANWU and JERRY (2017) in a suburban River in Umuahia, Southeast Nigeria. ANYANWU et al. (2019) also recorded lower number of individuals (119), higher taxonomic groups (5) and taxa (20) in an effluent-receiving river in Umuahia, Southeast Nigeria.

The number of individuals, taxonomic groups and taxa were affected by sand mining activities as reflected in the community structure. ZOU et al. (2019) reported reductions of 89.80% and 99.54%, respectively in the macroinvertebrate density and biomass, a significant reduction in the majority of macroinvertebrate taxonomic groups and species due substrate destruction and high turbidity associated with sand mining. SHEEBA (2009) also reported indiscriminate sand mining as one of the potential threats to the freshwater biota; through increased turbidity, reduced organic detritus supply, loss of breeding and spawning grounds.

The macroinvertebrate species recorded had some pollution tolerant species especially *Haliplus* sp larvae and *Chironomus* sp larvae. Tolerant organisms can survive in unstable environment because of their ability to cope with perturbations (MARIANTIKA and RETNANINGDYAH 2014) and become more abundant (KUCUK 2008). ZOU et al. (2019) recorded a decrease of 28% in macroinvertebrate density and an increase in the density of crustacea due to high turbidity in an area adjacent to the sand mining site. Decapod crustacean, *Caridina africana* was recorded in high numbers in all the stations. Station 3 had the highest number of individuals while station 2 had the lowest which could be as a result of the effect of sand mining activities in the station (SHEEBA 2009, ZOU et al. 2019). Benthic forms are severely destroyed and their re-colonization prevented by sand mining activities (BHATTACHARYA 2018). Macroinvertebrate abundance decreased temporally with increase in the amount of rainfall. MCCABE (2010) reported reduction of macroinvertebrate abundances by half or more as being usual after heavy rainfalls. The decrease could also be attributed to sand mining activities because the intensity usually increases with the rains (ANYANWU and UMEHAM 2020). It has been reported that rivers with unstable substrates tend to have low species diversity and the organisms present usually manifest characteristics of disturbed environments (COBB et al. 1992). Invertebrate drifting could also be responsible (NAMAN et al. 2016). Invertebrate drift could result from a number of factors; CASTRO et al. (2013) listed accidental dislodgement from the substratum, interaction with other organisms, water quality changes, discharge and current velocity. Some of these could be triggered by sand mining activities. KOEHNKEN et al. (2020) reported that sand mining affect macroinvertebrate drift, species abundance and community structures among others. The macroinvertebrate community structure showed signs of perturbation. BALLOCH et al. (1976) reported that the diversity indices can be used as suitable indicators of water quality. Species diversity indices are useful tools for comparing communities to identify biotic disturbances or level of stability (OLAWUSI-PETERS and AJIBARE 2014) and it increases as the habitat increases in complexity or stability (LEINSTER and COBBOLD 2012). The Shannon-Wiener diversity values recorded were in the range indicating perturbation especially in station 2. The Shannon-Wiener diversity index is usually from 1.5 to 3.5 and hardly exceeds 4.5 (MAGURRAN

1988, Bibi and Ali 2013). The index categories showed that values of < 1 indicated heavily polluted conditions, values of 1 to 2 indicated moderate polluted conditions and values of > 3 indicated stable environmental conditions (Stub et al. 1970, Mason 2002). The Margalef indices were equally low, also indicating environmental instability. Margalef index does not have upper limit value and varies according to the number of species. The pielou's measure of evenness was reduced especially in station 1. Leinster and Cobbold (2012) reported that evenness is an important aspect of diversity indices indicating the even distribution of the individuals within the different species. Shannon-Wiener diversity and evenness indices were slightly higher in station 3 indicating signs of possible recovery.

Conclusion

Certain anthropogenic activities have more adverse impacts on water quality and the biota than the others. This study has shown that indiscriminate sand mining have not adversely affected the water quality. However, the macroinvertebrate community was adversely affected which reflected in the presence of tolerant species and the community structure. The community structure gave an insight into the negative impact of sand mining. There is need to regulate sand mining in order to preserve the biotic components of such rural waterbodies.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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