Anthropogenic impact on environmental variables and macroinvertebrates community of River Eme, South-East, Nigeria

Anyanwu, E. D.[1*], Etusim, P. E.[2] and Umeham, S. N.[2]

[1]Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, Nigeria.
[2]Department of Animal and Environmental Biology, Abia State University, Uturu, Nigeria.
*Corresponding Author: Email: ekadon@yahoo.com

Abstract

Macroinvertebrates are good bioindicators of water quality and ecosystem health and are often used to study anthropogenic effect on aquatic ecosystems. Consequently, some environmental variables and macroinvertebrates of Eme river were studied to understand the impact of human activities on this socio-economically important ecosystem. Six stations (reflecting different anthropogenic activities) along the reaches of the river were sampled and analyzed monthly from December, 2017 to November, 2018 using standard methods. The results showed that water temperature varied from 22.00, station 1 to 28.5°C, station 6, turbidity (0.50-9.40 NTU, station 4), flow velocity (0.21, station 1-0.85m/s, station 3), pH (4.30, station 2-6.30, station 1), electrical conductivity (45.20, station 2-168.40µS/cm, station 5), dissolved oxygen (1.60, station 4-6.10mg/l, stations 3 and 4), biochemical oxygen demand (0.80-4.30mg/l, station 4), nitrate (1.10, station 3-5.6mg/l, station 4) and phosphate (0.40, station 3-4.6mg/l, station 4). Flow velocity, electrical conductivity, biochemical oxygen demand, nitrate and phosphate varied significantly between stations ($p<0.05$). A total of 584 individuals from 5 taxonomic groups and 23 species of macroinvertebrates were recorded. *Aquarius remigis* was the most abundant species (8.7%). The macroinvertebrate community was dominated by tolerant and very tolerant species, such as *Aquarius remigis, Caridina africana, Pseudocloen* sp. nymph, *Hydrometra* sp and *Belostoma* sp. The dominance of tolerant species, high turbidity, biochemical oxygen demand, nitrate and phosphate values and low dissolved oxygen values are strong indications of anthropogenic effect. It is suggested that adequate management attention should be paid to the river in order to prevent further deterioration.

Keywords: Water quality, macroinvertebrate, sand mining, biodiversity, anthropogenic activities.

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Introduction

Rivers are important freshwater resource as they serve as the primary source of water supply to several human communities and habitat to millions of aquatic organisms (Vörösmarty *et al* 2010). Globally, most freshwater bodies are being polluted as a result of human and natural processes, which affect ecosystem services (Mallin and Cahoon 2020). The status of aquatic ecosystem can be determined through the biological assessment of its biota (Santos and Ferreira 2020). Benthic macroinvertebrates are often used in the assessment of water quality and ecological status of aquatic ecosystems (Dallas 2021). The consistency and scientific reliability of macroinvertebrates use in biological assessments is predicated on their wide distribution, sensitivity to organic pollutants and ease of sampling at least cost (Leslie and Lamp 2017). Other considerations include their slow motility, extended life period, response to environmental changes and tolerance, which make them suitable to be used in the evaluation of specific pollutants in the aquatic environment (Duc *et al* 2015). They form an integral part of aquatic ecosystem and any negative disturbance can easily affect their community structure and trophic relationships (Akaahan *et al* 2016).

Indiscriminate sand mining is a common anthropogenic activity in most rivers in Southeast, Nigeria (including Eme river) and increases with increasing rainfall (Anyanwu and Umeham 2020). It is a major threat to the freshwater biota due to resultant habitat fragmentation, increased turbidity reduced organic detritus supply, and loss of fish breeding and spawning grounds (Sheeba 2009; Olaniyan *et al* 2019).

There are a number of studies on water quality and macroinvertebrate communities in Nigeria (Amusan *et al* 2018; Jonah *et al* 2020a, b; Anyanwu *et al* 2021). This

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study was aimed at determining the effects of anthropogenic activities on water quality and macroinvertebrate community of Eme river, Umuahia, South-east Nigeria.

Materials and methods

Study area and sampling stations

The source of Eme river is Uzoakoli in Abia State, Nigeria and it confluence Imo river at Onuimo. For the purpose of this study, the section of the river between Ofeme and Umudiawa, Umuahia, Abia State on either side of the Enugu-Port Harcourt expressway; a distance of about 3.25km was sampled. It lies between latitude 5°38′ and 5°37′N and Longitude 7°25′ and 7°26′E. The area falls within the sub-equatorial zone, characterized by high temperatures (29.00-31.00ºC), high relative humidity (over 70%) and annual mean rainfall of about 4000mm. Two distinct seasons characterize the area, the wet (June to November) and dry (December to May) seasons with a double maxima rainfall peak in July and September. A short period of dryness known as the "August break" usually occurs between the peaks (Nwankwo and Nwankwoala 2018). The river was divided into six stations based on accessibility and anthropogenic activities. All the stations have been previously dredged except station 1. Station 1, located within Ofeme community at Mbato, was upstream and some parts of the station were covered by trees. Laundry and extraction of water for drinking and other domestic purposes, especially during the dry season were observed. Several children were usually seen swimming during the dry season up to early rains because of its close proximity to human communities, easy accessibility and low water depth. Station 2 was located at the outskirts of the community (Eme-Ihite), about 1.84km downstream of Station 1. Laundry, swimming and extraction of water for drinking and other domestic purposes were also observed in the dry season. However, minimal sand mining was observed in the wet season. Station 3, also located in Eme-Ihite, close to the expressway, about 419.67m downstream of Station 2. No activities were observed except periodic boat movements during the wet season. Station 4 was located in Umudiawa community across the expressway, about 490.26m downstream of Station 3. This station was downstream to an area of intensive sand mining activities and two sand landing sites. Station 5 was about 200.22m downstream of Station 4; within Umudiawa community and there were sand mining activities. Station 6, also within Umudiawa community was about 300.14m downstream of Station 5 and in-channel and shoreline sand mining activities take place here.

Sample collection and analyses

Water samples

Water samples were collected from each site once a month between December, 2017 and November, 2018 with clean 1 litre plastic bottles. Water temperature was determined using a mercury-in-glass thermometer, pH,

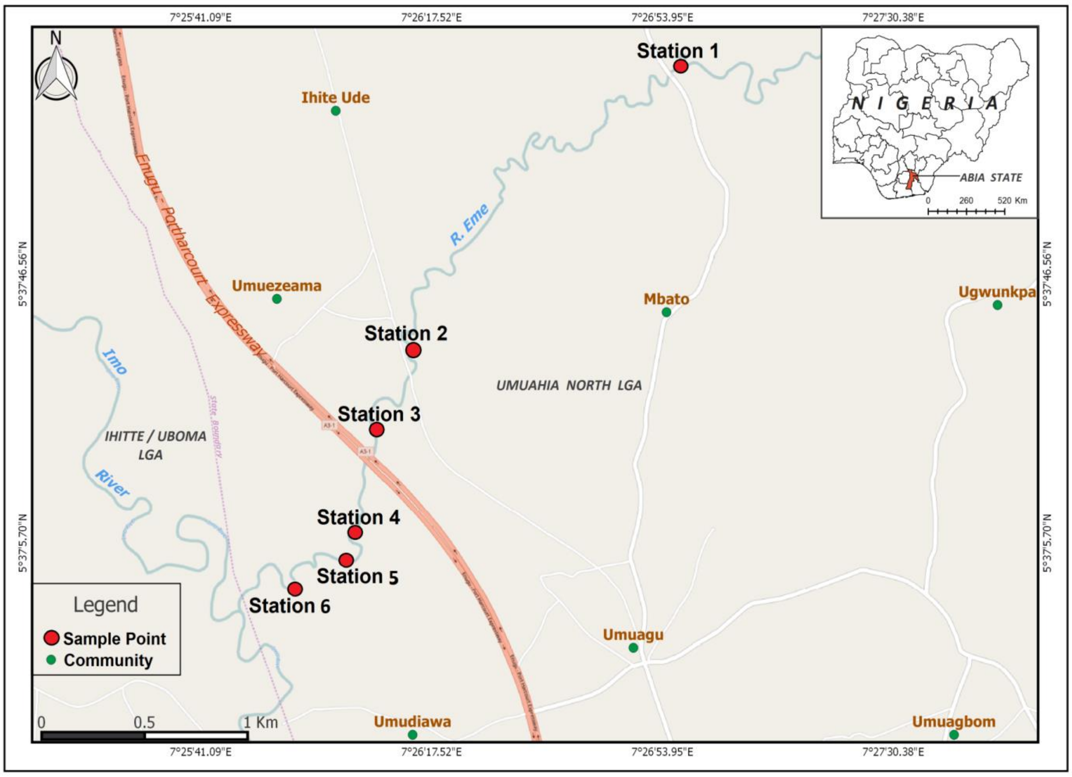

Figure 1. Map showing the sampling stations on River Eme, with an insert of map of Nigeria showing Abia State (Source: Anyanwu 2018)

conductivity and total dissolved solids (TDS) were determined using Hanna 3100 multimeter. Water velocity was determined by floating method, by measuring the time it takes a float to reach a predetermined distance in each site and the velocity computed as distance divided by time. Turbidity was determined using HACH 2100A turbidimeter. Dissolved oxygen was determined by Azide modification of Winkler's method. Nitrate and phosphate were determined by UV spectrophotometric and stannous chloride methods, respectively while BOD was determined after 5-day incubation as described by APHA (2012).

Macroinvertebrate sampling

Macroinvertebrates were sampled by modified kick sampling technique (Tubić *et al* 2017). Aquatic macrophytes along the bank of the river were vigorously disturbed with a hand net against the water current and dislodged macroinvertebrates were washed into the net (Tersoo *et al* 2017). The samples were preserved with 10% formalin in a plastic container and taken to the laboratory for proper sorting and identification according to the methods of Arimoro *et al* (2007). The sorted macroinvertebrates were identified to the species level using the taxonomic keys of Willoughby (1976), Brown (1994), 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 Microsoft Excel (version 2010). The differences between the means of the stations were tested using one-way analysis of variance (ANOVA) and, Tukey's pairwise comparisons test was performed to determine the location of significant difference ($p<0.05$). Macroinvertebrate species richness and diversity indices, Margalef (D), Shannon-Weiner (H) and Evenness (E) were computed using PAST statistical package (version 3.26).

Results

The results show that surface water temperature varied insignificantly from 22.00ºC (station 1) to 28.50ºC (station 6), $p>0.05$. Flow velocity values varied significantly between 0.21m/s in station 1 to 0.85m/s in station 3, $p<0.05$ (Table 1). The river was acidic and pH values ranged between 4.30 (station 2) and 6.30 (station 1), variation between stations was not significant ($p>0.05$). The electrical conductivity (EC) values ranged between 45.20µS/cm (station 2) and 168.40µS/cm (station 5). Conductivity values were significantly higher in the downstream stations (4-6) than the upstream stations (1-3) ($p<0.05$). Dissolved oxygen varied between 1.60mg/l in station 4 to 6.10 mg/l in stations 3 and 4. Biological oxygen demand (0.80-4.30mg/l) varied significantly between stations ($p<0.05$). Nitrate values were 1.10-5.60 mg/l and was significantly higher in station 4 ($p<0.05$) than in the other stations. Likewise, phosphate values (0.40-4.60 mg/l) were significantly higher in stations 4-6 compared to stations 1-3.

A total of 584 individuals from 5 taxonomic groups and 23 species were recorded (Table 2). *Aquarius remigis* (Water strider) was represented by the highest number of individuals (51) while *Paederus fuscipes* (Rove beetle), *Macromia* sp nymph (River Cruiser) and *Melanoides tuberculata* (Red-rimmed melania) had the lowest number of individuals (1). Most of the encountered species were either tolerant or very tolerant species except *Psephenuss* sp larvae and *Argyroneta aquatica* (Table 2). The dominant taxonomic group was Insecta with 504 individuals from 21 species and relative abundance of 86.2% while the least was Gastropoda with 1 individual from 1 species and relative abundance of 0.2%.

Species abundance ranged between 55 and 175 individuals among the stations (Table 3). The lowest abundance was recorded in station 4 while the highest was recorded in station 1. Analysis of variance (ANOVA) showed that species abundance in station 1 was significantly ($F=5.09$, $p<0.05$) higher than stations 3-6. The Shannon-Weiner diversity index ranged from 2.56-2.78 among the stations. The lowest value was recorded in station 5 while the highest was recorded in station 1. Margalef's species richness ranged between 2.98 and 3.74. The lowest value was recorded in station 2 while the highest value was recorded in station 4. The perturbed downstream stations (4-6) had relatively higher Margalef's species richness than the less perturbed stations especially station 2. The evenness values ranged between 0.85 and 0.96. The lowest value was recorded in station 1 while the highest value was recorded in station 2.

Discussion

The surface water temperature of River Eme was consistent with values commonly recorded in tropical rivers and adapted to by most tropical aquatic organisms Dallas 2008; Deekae *et al* 2010). The relatively higher values of flow velocity recorded in stations 2 and 3 could be attributed to riverbed gradient and widths of the river in the stations as suggested by Ekpo *et al* (2012) and Ames (2018). The relatively lower values of some parameters (turbidity, electrical conductivity, biochemical oxygen demand, nitrate and phosphate) observed in stations 2 and 3 could be attributed to reduced human activities and high water velocity compared to other stations. Flow velocity can significantly affect the capacity of a water body to assimilate and transport pollutants (Effendi *et al* 2015).

The high turbidity values observed in some stations, especially those downstream sand mining sites may be attributed to continuous sand extraction. Sand mining has been reported to increase turbidity in rivers (Ashraf *et al* 2011; Peck Yen and Rohasliney 2013) and this

Table 1: Means±SE and range values of environmental variables of Eme river, Southeast, Nigeria

Parameter	PO_4 (mg/l)	NO_3 (mg/l)	BOD (mg/l)	DO (mg/l)	E C (µS/cm)	pH	FV (m/s)	Turbidity (NTU)	W. Temp. (°C)
Station 1	$1.31±0.08^a$ (1.00-1.90)	$2.85±0.30^b$ (1.80-4.90)	$1.74±0.14^{ab}$ (1.00-2.50)	3.68±0.38 (2.30-5.70)	$85.96±4.40^a$ (55.60-115.80)	5.69±0.11 (5.00-6.30)	$0.35±0.02^a$ (0.21-0.49)	4.20±0.61 (1.50-9.30)	24.78±0.59 (22.00-28.00)
Station 2	$0.82±0.10^a$ (0.50-1.70)	$2.20±0.17^b$ (1.30-3.20)	$1.50±0.08^b$ (1.10-1.90)	3.58±0.34 (2.20-5.90)	$71.26±4.43^a$ (45.20-95.40)	5.43±0.13 (4.30-5.90)	$0.56±0.04^b$ (0.37-0.80)	3.52±0.52 (1.30-8.10)	24.85±0.54 (22.50-28.20)
Station 3	$0.68±0.07^a$ (0.40-1.20)	$1.60±0.12^a$ (1.10-2.40)	$1.67±0.12^b$ (1.10-2.40)	3.68±0.40 (1.80-6.10)	$65.71±3.50^a$ (49.60-88.70)	5.42±0.10 (4.90-6.10)	$0.71±0.02^c$ (0.63-0.85)	3.03±0.48 (0.60-5.40)	24.83±0.53 (23.00-28.20)
Station 4	$3.38±0.18^b$ (2.80-4.60)	$4.48±0.20^c$ (3.40-5.60)	$2.62±0.37^{ac}$ (0.80-4.30)	3.92±0.46 (1.60-6.10)	$130.39±5.86^b$ (90.30-160.20)	5.53±0.10 (5.00-6.10)	$0.36±0.02^a$ (0.24-0.46)	4.98±0.72 (0.50-9.40)	24.93±0.51 (23.20-28.40)
Station 5	$2.72±0.22^{bc}$ (1.90-4.30)	$2.61±0.37^{ab}$ (1.20-5.30)	$1.94±0.20^{ab}$ (1.00-3.20)	3.63±0.37 (2.00-5.50)	$115.44±6.04^b$ (88.50-168.40)	5.49±0.10 (5.10-6.20)	$0.37±0.02^a$ (0.28-0.50)	3.85±0.61 (0.70-7.80)	24.68±0.53 (23.00-28.30)
Station 6	$2.85±0.21^{bc}$ (2.00-4.50)	$2.89±0.27^b$ (1.90-5.20)	$2.13±0.25^{ab}$ (0.90-3.90)	3.77±0.42 (1.80-5.80)	$119.64±5.38^b$ (87.10-148.40)	5.55±0.10 (5.10-6.10)	$0.45±0.0^a$ (0.26-0.58)	4.18±0.56 (0.90-6.90)	24.75±0.53 (22.90-28.50)
P-value	P<0.05	P<0.05	P<0.05	P>0.05	P<0.05	P>0.05	P<0.05	P>0.05	P>0.05
NESREA (2011)	3.5	9.1	3	6	-	6.5-8.5	-	-	<40

means along the row with the different subscript letter are significantly different at p>0.05; NESREA = Nigerian Environmental Standards and Regulatory Enforcement Agency

Table 2: Composition, abundance and distribution of macroinvertebrate fauna in Eme River, Southeast, Nigeria

Taxonomic Group	Taxa	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Total	RA	PS
Crustacea	*Caridina africana*	29	9	3	3	0	4	48	8.2	VT
Annelida	*Nais* sp	12	0	0	0	0	0	12	2.1	VT
Insecta	*Chironomus* sp larvae	6	0	0	0	0	0	6	0.9	VT
	Anopheles gambiae	4	0	0	0	0	1	5	0.9	VT
	Caenis sp. Nymph	10	7	4	5	4	7	37	6.3	T
	Pseudocloen sp. Nymph	16	12	6	3	3	10	50	8.5	T
	Cloen sp. Nymph	9	6	8	3	4	9	39	6.7	T
	Baetis sp. Nymph	12	7	5	4	5	5	38	6.5	T
	Macromia sp nymph	0	0	1	0	0	0	1	0.2	VS
	Dytiscus sp *adult/larvae*	1	0	0	1	0	0	2	0.3	VT
	Orectochilus sp	7	4	1	5	3	6	26	4.4	T
	Paederus fuscipes	0	0	0	0	1	0	1	0.2	VT
	Psephenuss sp *larvae*	0	0	3	0	0	0	3	0.5	S
	Aquarius remigis	12	9	6	4	7	13	51	8.7	T
	Nepa apiculata	7	8	4	3	9	4	35	6.0	VT
	N. cinerea	5	6	5	2	5	3	26	4.4	VT
	Ranatra linearis	10	6	4	0	4	3	27	4.6	VT
	Belostoma sp	8	10	10	6	6	5	45	7.7	VT
	Hydrometra sp	7	8	6	6	10	9	46	7.9	VT
	Corixa sp	7	8	6	3	4	5	33	5.6	VT
	Notonecta sp	6	4	4	2	1	4	21	3.6	VT
Arachinda	*Argyroneta aquatica*	7	5	7	4	3	5	31	5.3	S
Gastropoda	*Melanoides tuberculata*	0	0	0	1	0	0	1	0.2	T
Total		**175**	**109**	**83**	**55**	**69**	**93**	**584**		

Legend: RA=Relative Abundance, PS=Pollution Sensitivity, VS=Very Sensitive, S=Sensitive, T=Tolerant, VT=Very Tolerant

Table 3: Community Structures of Macroinvertebrate fauna in Eme River, Southeast, Nigeria

Biodiversity Indices	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Taxa (S)	19	15	17	16	15	16
Individuals	175^{a}	109^{ab}	83^{b}	55^{b}	69^{b}	93^{b}
Shannon-Weiner (H)	2.78	2.66	2.72	2.67	2.56	2.64
Evenness (E)	0.85	0.96	0.89	0.90	0.86	0.879
Margalef (D)	3.49	2.98	3.62	3.74	3.31	3.31

means along the row with the same subscript letter are not significantly different at p>0.05

could adversely affect primary productivity and sensitive organisms (Sheeba 2009; Kale 2016; CEDA 2020).

The pH value in all the stations was acidic and attributable to both geogenic and anthropogenic influences. Geogenic low pH is associated with acid-generating rocks/soils and oxidation-reduction processes within the river (USEPA 2022). Sand mining also lowers the pH of water bodies (Seiyaboh *et al* 2013; Akankali *et al* 2017). Extremes of pH are unsuitable for most aquatic organisms. Aquatic organisms are extremely sensitive to pH levels below 5 and death may arise at these low pH values (Kale 2016).

The dissolved oxygen level in the river was quite low and was sometimes below 2mg/l, which is below the requirements for sustenance of most aquatic organisms (NESERA 2011). Persistently low DO could be attributed to disturbance and pollution (Rao *et al* 2013). Although the BOD and nitrate levels in this study were moderate, the phosphate level was high, which suggests possibilities of organic pollution that could be responsible for the low DO. Sand mining and other anthropogenic activities in water have been reported as major causes of such conditions (Ogbuagu 2013; Akankali *et al* 2017). Sand mining enhances the release and circulation of organic matters from the sediments into the water column, which increase BOD levels (Ogbuagu 2013; Akankali *et al* 2017). This condition can lead to decline aquatic biodiversity.

Macroinvertebrates have been extensively used to assess water quality, ecosystem health and impacts of anthropogenic activities (Anyanwu *et al* 2019; Blocher *et al* 2020). Anthropogenic activities observed in Eme river, especially sand mining could have negatively affected the abundance of the macroinvertebrates fauna. Sand mining affects aquatic biota through habitat destruction and increased turbidity (Sheeba 2009; Olaniyan *et al* 2019). The 584 individuals recorded were lower than 676 individuals recorded by Arimoro and Keke (2017) in Gbako River, North Central, Nigeria and 617 individuals by Amusan *et al* (2018) in Ona and Opa Rivers, Southwestern Nigeria. However, lower abundance (429 individuals) was recorded by Jonah *et al* (2020a) in Etim Ekpo River, South-South, Nigeria; that was also subjected to sand mining.

Furthermore, most of the species recorded were mostly tolerant or very tolerant species (Chessman 2003); this could be attributed to anthropogenic activities especially sand mining (Olaniyan *et al* 2019). Tolerant species have mechanisms to cope with environmental perturbation (Mariantika and Retnaningdyah 2014) and as a result usually occur in large numbers in disturbed environments (Kucuk 2008). The abundant species (*Aquarius remigis*, *Pseudocloen* sp and *Caridina africana*) encountered in this study have been reported in other Nigerian freshwater systems (Anyanwu and Jerry 2017; Jonah *et al* 2020b; Anyanwu *et al* 2021). The dominant taxonomic group was insecta as reported by Arimoro and Keke (2017), Anyanwu *et al* (2019), Keke *et al* (2020) and Anyanwu *et al* (2021) but different from the dominance of mollusca in Anyanwu and Jerry (2017).

The Shannon-Weiner diversity index values in this study were < 3, indicating environmental perturbation but were higher than the 1.28-1.33 recorded in Oluwa River, Ondo State (Olaniyan *et al* 2019). The structure of a habitat is considered stable and balanced when the values are > 3.0 (Türkmen and Kazanci, 2010). The lowest value recorded in station 5 could be due to sand mining activity (Ekpo *et al* 2012). Important information about the structure of a river can be obtained using the diversity indices (Türkmen and Kazanci 2010). Shannon-Weiner diversity index is the most preferred (Türkmen and Kazanci 2010). The index values are between 0.0 and 5.0 but the results are usually between 1.5 and 3.5; rarely exceeding 4.5 (Bibi and Ali 2013).

Conclusion

The study revealed the paucity of macroinvertebrate in the river and dominance of disturbance tolerant species. These were attributed to high turbidity and low dissolved oxygen occasioned by regular sand mining in the river and other anthropogenic activities such as recreation. These activities if uncontrolled could lead to extirpation of ecological important biota, which could lead to loss of biodiversity. It is suggested that adequate management attention be paid to the river to prevent further deterioration.

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