IJABR Vol. 9(2): 166 - 179 (2018)

Original article

Diversity and Community structure of Macroinvertebrates in Anthropogenically stressed water body in Delta state, Nigeria.

Iloba, K. I[1], Akawo, O. N[2] and Nwaefiene, F[1]

[1]Department of Animal and Environmental Biology, Delta State University, Abraka
[2]Department of Biology Education, Federal College of Education (Technical) Asaba

Submitted: December, 2017; Accepted: May, 2018; Published: June, 2018

ABSTRACT

The macroinvertebrate community of Agbara- Otor River system at Agbara-Otor, Omavovwe and Afiesere in Delta state were studied, to evaluate the ecological impact of dredging on their community structure from March to May, 2017. Kick sampling method was adopted for macroinvertebrate sample collection. Two litres of water sample was also collected for the evaluation of the environmental variables. The range of results for air temperature(31.0-37.5°C), water temperature(27.3-32.3°C), transparency (0.03-0.81m), total solids (0.35-0.7mg/L), conductivity (27.03-51.6 µm/Scm), pH (7.8-9.7), alkalinity(13.0-33.3mg/$CaCO_3$), acidity (25.0-72.5), dissolved oxygen (3.1-5.7mg/L), biochemical oxygen demand (1.53-5.7mg/L), nitrates (0.005-0.006mg/L) and phosphates (1.13-1.67mg/L) were obtained. A general low taxa (7) comprising of 403 individuals with15 families were recorded. Coleoptera (41.2%) was the dominant family, followed by Odonata (16.1%), Ephemeroptera (10.7%), Hemiptera (10.4%), Trichoptera (9.93%), Decapoda (8.68%) and the least, Diptera (2.98%). The highest diversity indices range for Shannon-weiner of 1.6-1.7 was obtained indicating very poor water quality and unstable system. The first axes of the three principal components in all stations extracted over 90% of the macro invertebrates- environmental variables influence implicating nutrients, organic load and sediments. Therefore, this study identified dredging as a serious threat to this water quality and its macroinvertebrates. Targeted ways of dredging must be adapted to reduce ecological impacts and allow for re-establishment and protection of macroinvertebrates and improved water quality.

Keywords: Agbara –Otor River system, dredging, diversity indices, principal component analysis and macroinvertebrates

***Corresponding author**: iloba@delsu.edu.ng; kisyiloba@gmail.com

INTRODUCTION

Globally, the number of anthropogenically stressed water bodies due to man's dependence on its resources is on the increase and of great concern. The exploitation of these resources has been reported to have ruinous impacts on river resources including its flora and fauna with their associated habitats (Matthews, 2016).

The composition and abundance of biological community of a water body reflects the health status of the water body at that point (Obolewski *et al.* 2014; Kutty *et al.* 2016). Aquatic species are therefore selective of the micro-habitat they occupy, depending on their nutritional and ecological requirements as well as the prevailing anthropogenic activities. In other words, habitat destruction due to anthropogenic activities has serious modifications on the habitats of array of organisms found in these water bodies, particularly the relatively sessile macrobenthic invertebrate fauna (Iloba and Ikechukwu, 2014). Several researchers have noted that the complexity, diverse, distribution and abundance of macro invertebrates in lotic water bodies are structured by both natural and anthropogenic factors which depends on the characteristics of their environment such as, pollution condition, organic matter content, soil texture, sediment type, recreation, food and employment (Poznanska *et al*; 2009; Zhang *et al.*, 2014; Tornwell *et al.;* 2015; Barbosa *et al.* 2016). Thus the structure and function of macroinvertebrates reflects the physical and chemical conditions of the environment, and changes with increased human influence (Karlston *et al.* 2002). Their success as indicators of water quality is due to their outright selective sensitivity and tolerance to stress factors in the environment (Ravera, 2001; Arimoro *et al.* 2008; Iloba and Ikechukwu, 2014; Arimoro *et al.* 2015).

Agbara-Otor River system has been subjected to dredging activities for several decades in response to rapid urbanization in the area. Urbanization through road construction and building of houses (bricks) will have profound impact on the water body which is the major source of sharp sand in this area. Although there are numerous works on macroinvertebrate communities in Nigeria, very little have been reported on the macroinvertebrates communities of a dredged river (Ogbeibu, 2010). This work therefore intends to determine the water quality of the Agbara-otor river system under intensive dredging by assessing the diversity and community structure of macroinvertebrate communities in this anthropogenically stressed water body.

MATERIALS AND METHODS

Study area

Agbarha-Otor River is a freshwater body in Ughelli North Local Government Area of Delta State. The river lies within longitude 6°12'-5°12'N and latitude 5°45'-5°13'E of the equator (Fig. 1). The river is swift flowing and overflows its channel during the flooding period. The substratum consists mainly of silt, fine and coarse sand. There are two main seasons in this region; the wet season (April to October) and dry season (October to March). Three study stations were chosen randomly and were labeled Stations 1, 2 and 3, for ease of identification. Station 1 is located at Agbara-Otor and is characterized by swift flow with the riparian vegetation consisting of mainly bamboo tree (*Bambussa mimosa*) and aquatic macrophytes such as, *Pistia stratiotes*. Human activities dominant here are sand dredging, swimming and fishing. Station 2 is located at Omavovwe, a slow moving region of the river. *Luffaov egytiaca* and *Panicium maximum Pistia stratiotes* and *Bambussa mimosa* were the dominant plants in this station. Dredging and swimming prevalent human activities in this station. Station 3 is located at the Afiesere portion of the river. It is fast flowing, with sandy bottom.

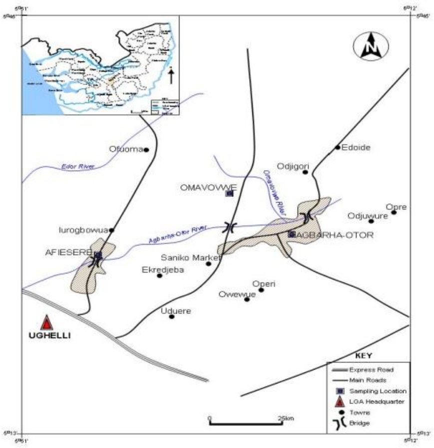

Fig 1: Map of study location showing sampling stations

The major human activities include sand dredging, car washing and swimming. Aquatic macrophytes associated with this station were *Hydroleap alustris* and *Panicum maximum*.

Determination of Environmental variables:

Surface water temperature and air temperature were measured *in situ* with a mercury-in-glass thermometer. The following variables; hydrogen ion concentration (pH), Dissolved Oxygen (DO), Biological Oxygen Demand(BOD), alkalinity, acidity, transparency, conductivity, total dissolved solids, total suspended solids, nitrate and phosphate were measured using APHA (1998).

Macroinvertebrates Sampling

The kick sampling method described by Lenat *et al.* (1981) was adopted in this study. The substratum and the emergent vegetation were vigorously disturbed by kicking upstream. Dislodged animals from the streambed were washed in by current into D-framed net of mesh size (800µm) held in downstream position. Collected samples were preserved with 10% Formalin and taken to the laboratory for enumeration and identification of invertebrates to the lowest practical taxon under a binocular dissecting microscope. Identification was done using keys and references provided by Hawking (2000), Theischinger (2001) and Arimoro and James (2008).

Data Analysis

Differences between the environmental variables at the stations were tested by one-way Analysis of variance (ANOVA) using Statistix 8 statistical package. Biological diversity indices; Margalef richness index, Shannon-weiner index, Evenness, Simpson dominance index, Menhinick index were used to analyze the macroinvertebrates community structure. Principal component analysis (CCA) based on correlation was used to evaluate relationships between macrobenthic invertebrate communities and environmental variables using PAST statistical package (Hammer et al. 2001).

RESULTS

The mean, standard deviation and P-values of the physical and chemical parameters investigated area are shown in Table 1. There were statistically significant variations in the environmental variables in the present study ($p< 0.05$) as shown in Table 1. Of obvious ecological importance in this study were the high significant differences in the Solids among the sampling stations and the rapid changes in the transparency of the stations (CV > 100). Of the fourteen (14) environmental variables, nine (9) were statistically different between the stations reflecting habitat differences. The air temperature ranged from 30°C to 40°C. The highest value of 40°C was recorded in April in station 3 while the least value 30°C recorded was in May in station 1. The monthly water temperature ranged from 26°C – 35°C. The highest value of 35°C was recorded in March in station 3 while the least value recorded was in April in station 1. The monthly pH values varies from 6.9 – 10.7. The highest value of 10.73 was obtained in station 2 in April while the lowest value 6.9 was recorded in station 3 in March. The highest total solid (0.8mg/l) was recorded in March in station 3 and the lowest recorded was (0.33mg/L) in March in station 1. The highest conductivity value was obtained in station 3 April (62.9 µm/Scm) while the lowest value 23.8 µm/Scm was recorded in station 1 in April. Nitrate was highest in March (0.092mg/L) in station 3 and the least value was recorded in May (0.003mg/L) in station 3. The highest value (1.87mg/L) was recorded in April in station 2 and the least value was recorded in station 1 in March (0.75mg/L). The highest value recorded for alkalinity was 41 mg/L April in station 2 and the least value was 10mg/L in March and May in station 3. The highest value recorded for acidity was 90mg/L May in station 3 and the least value was 15.00mg/L April in station 2. Dissolved oxygen was highest in May (6.90mg/L) in station 3 and the lowest in April (2.10mg/L) in station 2. The highest biochemical oxygen demand (6.10mg/l) was recorded in May in station 1 and the lowest recorded was (0mg/L) in March in station 3. The highest value was obtained in station 1 in May (1.3m/L) while the lowest value 0.3m/l was recorded in station 2 in March, April and May.

Macroinvertebrate composition and abundance:

The relative abundance of the macroinvertebrates encountered in Agbarha-Otor River in the study is shown in Table 3. Thirteen (13) families belonging to seven orders represented a total of four hundred and three individuals (403). The Coleopteran (41.2%) constituted the largest and most dominant followed by the Odonata (16.1%), Ephemeroptera (10.7%), Hemiptera (10.4%), Trichoptera (9.93%), Decapoda (8.68), with the least Diptera (2.98%)(Fig. 2).The present study showed varying macroinverbrates abundance in the station and time (Fig. 3).Organically sensitive coleopterans, Appasus sp. (Belostomatidae) was abundant particularly in stations 1 and 3. The order Ephemeroptera was scarce and sporadic suggesting an impaired water body as they are known to occupy clean waters. Sensitive Cloeon sp. occurred once in station 2 during the study. This is an indication of an organically impaired environment. Sensitive dipterans were insignificant in the system

Table 1: Environmental variables (± SD) for each station of the Agbaro-otor river system

Stations/ Parameters	Station 1	Station 2	Station 3	Grand Mean	CV	F-Value	P-Value
Air temperature ^{o}c	32.5±1.72	33.7±2.00	35.4±2.32	33.9	5.99	5.16	0.0126*
Water temperature ^{o}c	28.3±2.06	29.5±2.27	31.7±2.45	29.8	7.60	5.79	0.0081*
Transparency m	0.40±0.53	0.04±0.008	0.14±0.15	0.19	166.4	3.53	0.0453*
TS mg/L	0.47±0.08	0.40±0.06	0.06±0.12	0.49	18.97	12.6	0.0001*
TDS mg/L	0.19±0.04	0.18±0.02	0.30±0.08	0.23	23.16	15.1	0.0000*
TSS mg/L	0.27±0.07	0.21±0.05	0.30±0.07	0.26	24.58	4.79	0.0166*
Conductivity µm/Scm	27.20±3.03	37.0±3.84	46.6±10.6	37.0	18.21	20.7	0.0000*
pH	8.70±1.03	8.90±1.36	8.40±1.46	8.60	14.95	0.26	0.7742*
Alkalinity mg/L $CaCO_3$	25.0±7.82	28.5±7.84	21.1±8.36	24.87	32.2	2.14	0.1375*
Acidity mg/L $CaCO_3$	40.5±16.1	30.0±18.11	53.0±22.01	41.17	45.88	3.72	0.0375*
BOD mg/L	3.34±1.73	2.86±1.16	3.95±2.0	3.38	49.23	1.08	0.3553*
DO mg/L	4.30±1.05	4.10±1.35	4.70±1.31	4.40	28.39	0.59	0.5614*
Phosphate mg/L	1.45±0.33	1.48±0.30	1.49±0.16	1.47	18.65	0.05	0.9489*
Nitrate mg/L	0.02±0.002	0.02±0.005	0.04±0.04	0.03	77.31	4.37	0.0227*

*CV (Coefficient of variation)>45.0; $P < 0.05$ significant difference

Table 2: Composition, distribution and abundance of macroinvertebrates in Agbarha-Otor River from March to May, 2017

			Station 1			Station 2			Station 3		
Order	Family	Species	Mar.	Apr.	May.	Mar.	Apr.	May.	Mar.	Apr.	**May.**
Decapoda	Atyidae	*Cardina gabonensis*	-	-	-	-	3	-	2	-	-
		Caridina nilotica with egg	-	-	2	4	-	-	-	-	-
		Cardina nilotica without egg	8	-	-	3	-	2	-	-	**5**
		Macrobrachum dux	-	2	1	-	-	-	3	-	-
Trichoptera	Hydropsychidae	*Aethaloptera maxima*	5	-	11	6	-	5	-	13	-
Ephemeroptera	Baetidae	*Baesti sp*	-	16	-	5	-	-	2	-	**8**
		Cloeon sp	2	-	-	-	-	-	-	-	-
		Bugilliesia sp	-	1	-	-	3	-	-	6	-
Odanata	Libelluidae	*Brachythemia*	7	-	-	8	-	-	-	-	-
		Leucostica	-	-	3	-	6	-	1	10	**2**
		Bradinopyga	-	-	-	-	-	8	5	-	-
	Aeshinidae	*Aeshna minuscule*	6	1	-	-	5	-	-	3	-
Diptera	Chiromidae	*Orthcladiinae*	2	-	-	-	-	-	6	-	-
	Culicidae	*Pupa(Wriggler)*	-	-	-	-	-	3	-	-	**6**
Hemiptera	Naucoridae	Naucoris sp.	-	-	6	-	-	-	-	-	**1**
	Nepidae	Ranatra sp.	12	-	-	8	-	-	4	2	-
	Velidae	Velus sp.	-	-	-	-	-	4	-	-	**6**
Coleopteran	Dytiscidae	*Methles sp.*	6	3	2	-	-	-	-	-	-
		Hyphydrus sp.	11	-	4	6	-	-	5	-	-
		Coelhydrus sp.	-	-	-	1	-	7	-	-	-
		Philaccolus sp.	-	2	-	-	4	-	-	1	-
		Philodytes sp.	-	-	-	3	-	-	-	-	-
	Curculionidae	*Curculionis sp.*	2	-	-	-	5	-	4	-	-
	Belostomatidae	Apasus sp	6	14	11	-	-	5	6	16	**42**
Total			67	39	40	44	26	34	38	54	**64**
Grand Total			**146**			**104**			**153**		

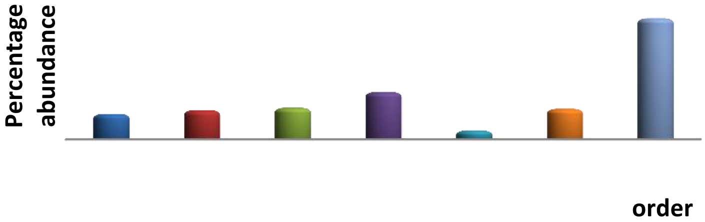

Fig 2: Percentage abundance of the macroinvertebrates in the Agbara- Otor river system.

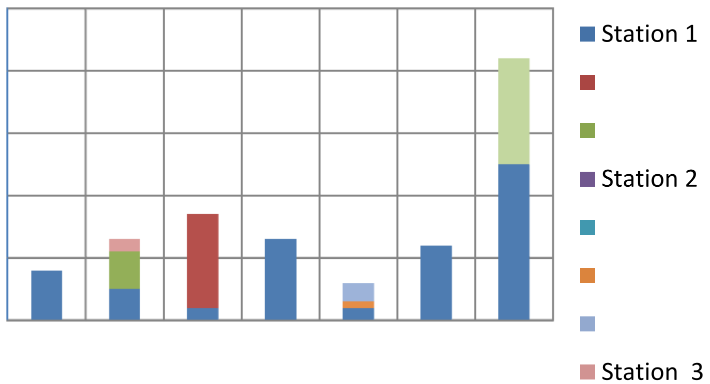

Fig. 3: Spatio-temporal distribution and relative abundances of macroinvertebrates in Agbara - Otor river system

Diversity Indices

The diversity indices were generally very low as shown in Table 3. The Margalef index was highest in station 2 (1.292) and lowest at station 3 (1.191). Generally, the diversity indices calculated for this study were highest in station 2 except Simpson's dominance index which was highest in station 3 and lowest in station 2 with 0.271 and 0.193 values respectively

.

Table 3: Diversity Indices of Macro-benthic Invertebrates in the studied station

Indices	Station 1	Station 2	Station 3
Margalef Richness Index (d)	1.204	1.292	1.191
Shannon wiener (H+)	1.650	1.760	1.601
Evenness (E)	0.851	0.901	0.820
Simpson dominance (C)	0.235	0.193	0.271
Menhinick Index	0.572	0.682	0.566

In other to determine the impact of each physico-chemical parameter on the fauna abundance, Principal component analysis (PCA) was performed. In all Stations, three principal components with relatively high score values (Table 4) accounted for over 90% of the macro invertebrates- environmental variables influence (Table 4) in PC 1 alone. In station 1, axis 1 accounted for over 90% of the variations with eigen value of 2.352, axis 2 and 3 were of less significant. Axis 1 contributed highest to the total variation recorded in station 2, with a value of 96.6% with an eigen value of 2.12. The contribution of axis 2 and 3, were not significant, while axis 1 contributed 94.95% to the total variation recorded in station 3, with an eigen value of 2.17742. The contributions of axis 2 and 3 were not significant. Figure 4, showed that acidity, alkalinity, air and water temperature, and conductivity positively correlated with coleopteran and occurred on the positive axis on the plot. Nitrate, Total dissolved oxygen, dissolved oxygen, diptera, decapoda, trichoptera, hemiptera and odonata all occurred on the negative axis. pH, dissolved oxygen, alkalinity, acidity, conductivity, air temperature and water temperature were strongly associated with Coleoptera fauna. Hemiptera, Trichoptera, Decapoda, Coleoptera and Ephemeroptera were positively impacted, while Odonata and Diptera were negatively impacted on the PCA ordination chart (Station 2).While conductivity, water temperature, air temperature, alkalinity and acidity correlated positively with the dominance of Coleoptera in station 3. It also revealed a relationship between Nitrate, TDS, TSS, TS and transparency of the river

DISCUSSION

This study recorded relatively high values for certain environmental parameters particularly, air and water temperatures, pH, alkalinity and biochemical oxygen demand, while the values recorded for dissolved oxygen, nitrate and conductivity were low. The surface water temperature recorded in this study was however within the range recorded for other water bodies within the area by Arimoro *et al.* (2007), Iloba and Akawo,(2013), Ikomi and Arimoro (2014) and Arimoro *et al.* (2015). The high water temperature could be attributed to the efficiency in heat transfer from the surrounding environment, since the air temperature was equally high (31^0C-37.5^0C).

The dissolved oxygen values were low in this study. However, it falls within the ranges recorded in similar climes by Iloba and Akawo, (2013), Ikomi and Arimoro (2007) and Arimoro and Ikomi, (2008). According to Morrison *et al.* (2002), increasing water temperature affects the self-purification capacity of rivers by reducing the amount of oxygen that can be dissolved and used for biodegradation. The low dissolved oxygen value can also be attributed to the low transparency of the river. This reduces the level to which light penetrates the water and hence reduces the oxygen fixing ability of algae in the water.

pH level recorded in this study was alkaline. The pH levels recorded for the three stations were statistically not significant ($P\leq0.05$).The range of values for pH is 7.78-9.69. This is similar to the report of Edokpayi *et al.* (2010) in Lagos Lagoon. This is generally high for a river flowing through a forest (Arimoro, 2010). The alkaline pH noted may be attributed to discharge of effluents of inorganic nature into the river, presumably automobile waste materials. High alkalinity of water bodies have been implicated has responsible for physiological stress on aquatic fauna and flora, as well as the loss of aquatic biodiversity (Edokpayi *et al.* 2010). Alkalinity values ranging between 13.0-33.3mg/L $CaCO_3$ were recorded in this study. This was higher than values recorded for Iloba and Akawo, (2013) and Arimoro *et al.* (2007). This is an indication that Agbara-Otor River possibly has limestone in its drainage basin or there is an allochthonous source of carbonate or bicarbonate ions around the riparian communities.

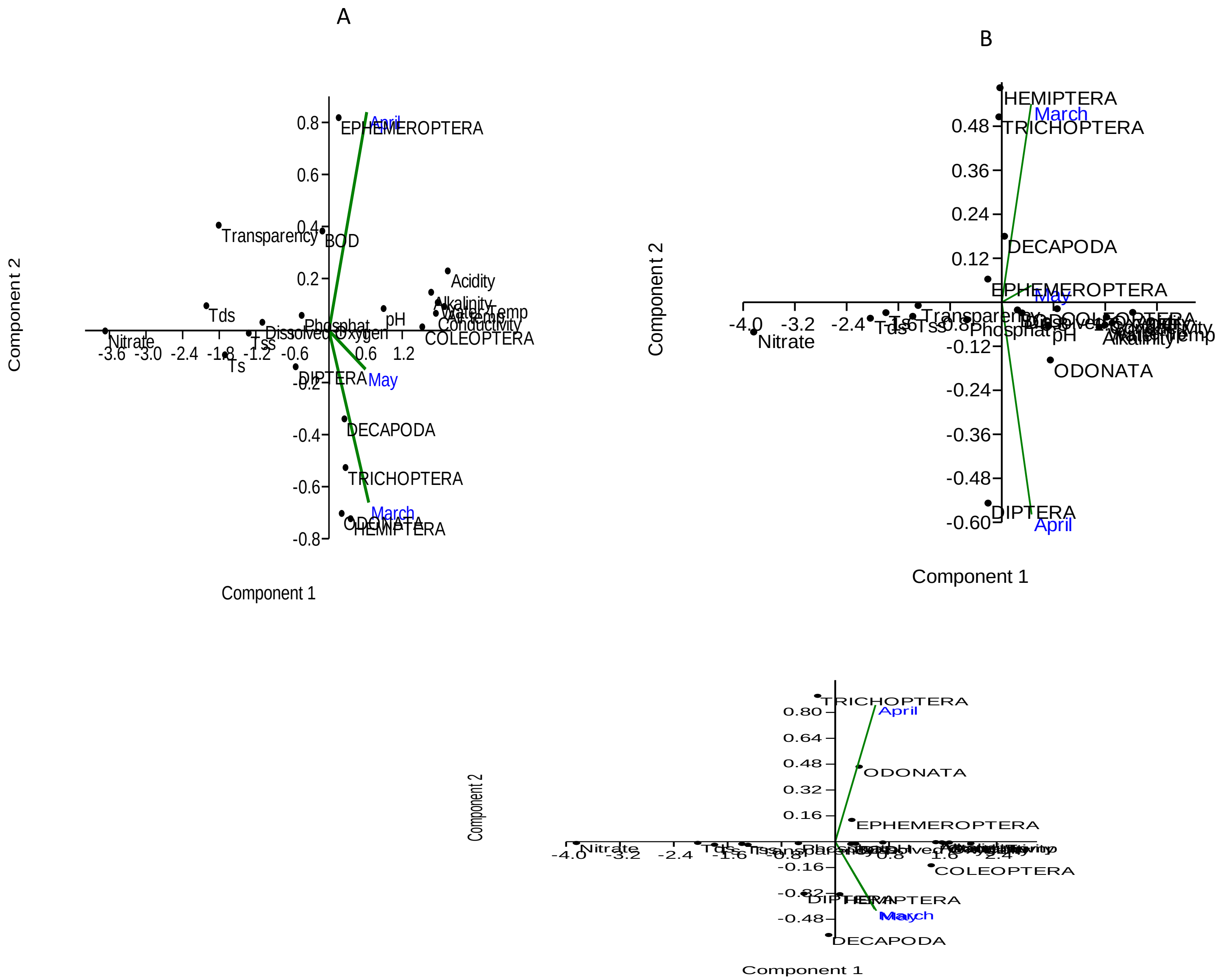

Figure 4: Principal Component Analysis (PCA) Plot of the first two principal components of the environmental variables and macroinvertebrates in Stations 1(A), 2(B) and 3(C)

T

able 4: Sample scores of the three Principal Component Analysis of the three stations in Agbara-Otor River System

Variables	Station 1			Station 2			Station 3		
	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3
Dissolved Oxygen	-1.0934			0.31409			0.30508		
BOD		0.38286	0.39401						
Alkalinity	1.6745			1.5057			1.4945		
Acidity	1.9471			2.0253			2.0154		
Conductivity	1.7529			1.6206			1.6103		
pH	0.89482			0.71813			0.7071		
Water temperature	1.7823			1.5962			1.585		
Air Temperature	1.8901			1.7069			1.6959		
Nitrate	-3.67			-3.837			-3.8472		
Phosphate	-0.44796			-0.53944			-0.54823		
Total dissolved solids	-2.0116			-2.0339			-2.0437		
Total solids	-1.7075			-1.7931			-1.794		
Transparency	-1.8092	0.40526	0.48256	-1.2938			-1.2976		
Total suspended solids	-1.3163			-1.3773			-1.3871	-	
DECAPODA		-0.33941						-0.57706	
TRICHOPTERA		-0.52635	0.42606		0.5056			0.90311	
EPHEMEROPTERA		0.8185	-0.54122			0.47444			-0.4238
ODONATA		-0.70286		0.7502			0.35567	0.46461	0.33932
DIPTERA	-0.54754				-0.54741		-0.4644	-0.32107	0.54345
HEMIPTERA	0.35339	-0.72305			0.58516			-0.32468	
COLEOPTERA	1.5295			0.85693	-0.017507		1.4265	-0.14583	
Eigenvalue	2.35157	0.126891	0.0556791	2.12296	0.0495662	0.02062	2.17742	0.08070	0.03511
%variance	92.796	5.0073	2.1972	96.8	2.26	0.94033	94.95	3.5193	1.5311

High BOD levels associated with this study (1.53-5.0 mg/L). However; it falls within the range described for some Nigerian streams (Edokpayi *et al*. 2010; Seiyaboh *et al*. 2013; Arimoro *et al*. 2015). High BOD in this study is an indication of physiological stress on the river quality, which may be due to nutrients loading by aquatic organisms or as a result of other anthropogenic activity such as dredging. The difference in B.O.D levels among the stations were not however significant (P≥0.5).

Habitat complexity is one of the key environmental factors influencing macroinvertebrate communities, providing more ecological niches, which make macro invertebrates highly vulnerable to the loss of their preferred habitat (McGoff *et al.* 2013). This study recorded low number of individuals of macrobenthic invertebrates (403 individuals), from just 7 taxa; as compared with the reports of Arimoro *et al*. 2007; Edokpayi et al. 2010 and Olomukoro and Ovioje 2015 where 36, 16 and 46 distinct taxa respectively were recorded. However; this study is similar to those of Arimoro *et al.* (2007) where Coleoptera was the dominant taxa. The low number of taxa recorded is as a result of the combined activity of dredging and other environmental factors despite their hardy nature. Dredging, which is the dominant human activity in Agbara-Otor River is responsible for habitat destruction, hence reducing the number of possibly available habitats to other taxonomic groups (Zhang *et al*. 2014). The existence of aquatic macrophytes in stations 1 and 2 must have encouraged and provided habitat for their survival. Coleoptera have shown preference to attaching to aquatic macrophytes (Valladares *et al.* 2002). In Agbara-Otor River, the aquatic macrophytes are the least affected by the dredging activity, hence organisms such as the coleopteran with preference for this niche most abundant, while those attached to sediments were the least recorded.

The dominance of organic loving Coleoptera in this study differs from Ogbeibu *et al.* (2010), where diptera was the dominant group. Clean cool water loving dipterans were virtually absent from the system due to the high silts, debris, organic load generated by the dredging activities significantly resulting in low transparency as well as its rapid fluctuations (CV = 146). This difference is an indication that, Agbara-Otor River is anthropogenically stressed. This is evident from the low biological indices values reflecting an unstable and impaired system all through the study. Low biotic indices have been reported in Nigeria and worldwide indicting anthropogenic disturbances (Poznanska *et al*. 2009; Horsak *et al*. 2009; Zhang *et al*. 2014; Arimoro *et al*. 2015; Fishar *et al*. 2015; Belal *et al*. 2016. The presence of other pollution sensitive taxa, like Ephemeroptera, Odonata and Trichoptera which closely followed the Coleoptera further validates this claim. This is also similar to the reports of Arimoro *et al*. (2007) in Orogodo River and Adakole and Annune (2003) in Bindare stream.

The resulting first principal components of over 90% at all stations recruiting all parameters except BOD with very high loading factors can be expained as impacts from sediments load (TSS, TDS, TS and transparency) nutrients(nitrate and phosphate), organic pollution (DO, BOD) hardness and alkalinity on structure and composition of macroinvertebrates in this study(Horsak, *et al.* 2009; Iloba, 2012; Arimoro *et al*. 2015). These lines of gradient are all human- related disturbances (Seiyaboh *et al*. 2013; Kaaya and Dallas, 2015; Belal *et al*.)

REFERENCES

Adakole, J. A. and Anunne, P. A, (2003). Benthic Macroinvertebrates as indicators of environmental quality of an urban stream, Zaria, Northern Nigeria. *Journal of Aquatic Science,* 18(2): 85-92.

APHA, (1998). American Public Health Association. Standard Methods for the examination of water and waste water. 20th Ed. APHA, Washington, D.C.

Arimoro, F. O, Ikomi R. B. and Iwegbue, C. M. A. (2007). Ecology and abundance of Oligochaetes and indicators of organic pollution in an urban stream in South Nigeria. *Pakistan Journal of Biological Sciences,* 10(3): 446- 453.

Arimoro, F. O. and James, H. M. (2008). Preliminary pictorial guide to the macroinvertebrates of Delta State Rivers, Southern Nigeria. Grahamstown: Albany Museum.

Arimoro, F. O. (2010). Microhabitat preference, diversity and ecology of aquatic mites in a municipal stream in the Niger delta*. Journal of Applied Biosciences, 27: 1687 – 1696. ISSN 1997- 5902.*

Arimoro, F. O., Odume, O. N., Uhunoma, S. I. and Edegbene, A. O. (2015). Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environmental Assessment and Monitoring,* 187:14 DOI 10.1007/s10661-014-4251-2

Barbosa, F. A. R., Callisto, M. and Galdean, N. (2016). The diversity of benthic macroinvertebrates as an indicator of water *and ecosystem health: a case study for Brazil. Aquatic Ecosystem health and Management,* 4(1):51 59.

Belal, A. A. M., El-Sawy, M. A. and Dar, M. A. (2016). The effect of water quality on the distribution of macro- benthic fauna in Western Lagoon and Timsah Lake, Egypt. 1. *Egyptian Journal of Aquatic Research,* 42: 437- 448.

Edokpayi, C. A., Olowoporoku, A. O. and Uwadiae, R. E. (2010).The hydrochemistry and macro benthic fauna characteristics of an urban draining Greek. *Int. Journal of Biodi. and Cons.*, 2(8): 196-203.

Fishar, M. R., El- Damhony, K. A. and Mola, H. R. A. (2015). Applying some biotic indices of macrobenthic invertebrates to assess water quality of Lake Manzala, Egypt. *Egyptian Journal of Aquatic Biology and Fish,* 19(2): 29-41

Hammer, O., Harper, D. A. T. and Ryan, P. D. (2001). PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica,* 4(1): 9 pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm Accessed 10 August 2017.

Hawking, J. H. (2000). A Preliminary guide to keys and Zoological information to identify invertebrates from Australian inland waters 2nd edn.Murray Darling Freshwater Research Publication, Australia. No.2, 71pp

Horsak, M., Bojkova, J., Zahradkova, S., Omesova, M. and Helesic, J. (2009). Impacts of reservoirs and channelization on lowland river macroinvertebrates: A case study from Central Europe. *Limnologica,* 39:140-151

Iloba, K. I. (2012). The Physico-chemical Characteristics and Plankton of Ethiope River, Nigeria. Ph.D Thesis, Delta State University Abraka, Delta State, 2012; 446

Iloba, K. I. and Akawo, N. (2013). The zooplankton of River Adofi in Delta state of

Nigeria. *Nigerian Journal of Science and Environment,* 12 (2): 25- 46.

Iloba, K. I. and Ikechukwu, M. O. (2014) Macrobenthic invertebrates and some water quality parameters in Ikpoba River, Edo State, Nigeria. *Jewel Journal of Scientific Research*, 2(1&2):165-173

Ikomi, R. B. and Arimoro, F. O. (2014).Effects of recreational activities on the littoral macroinvertebrates of Ethiope River, Niger Delta, Nigeria. *Journal of Aquatic Sciences*, 29(1): 155–170.

Kaaya, L. T. and Dallas, H. F. (2015). Tanzanian River Scoring System (TARISS): a macroinvertebrate- based biotic index for rapid bioassessment of rivers. *African Journal of Aquatic Science,* 40 (2):109-117

Kutty, R.. Chakkayil. M. and Pura, S. H. V. (2016). Community Structure of Macrobenthos in Ponnani estuary,South India with reference to occurrence of invasive alien species. *Int. J. Aquat. Biol, 4* (4): 269- 276.

Lenat, D. R., Penrose, D. L. and Eaglesor, K. W. (1981). Variable effects of Sediment addition on stream benthos. *Hydrobiol*., 79:187-194.

Matthew, N. (2016). People and freshwater ecosysytems: pressures, responses and resilience. *Aquatic Procedia,* 6: 99- 105.

Morrison, J., Quick, M. C. and Foreman, M. G. G. (2002). Climate change in the Fraser River watershed: flow and temperature projections*. Journal of Hydrology,* 263:230–244.

McGoff, E., Solimini, A. G., Pusch, M. T., Jurca, T and Sandin, L. (2013): Does Lake habitat alteration and land-use pressure homogenize European littoral macroinvertebrate communities? *Journal of Applied Ecology,* 50:1010–1018.

Obolewski, K., Glinska-Lewezuk, K. and Strzelczal, A. (2014) The use of benthic macroinvertebrate metrics in the assessment of ecological status of floodplain lakes. *Journal of Freshwater Ecology*, 29(2): 225- 242

Ogbeibu, A. E., Arazu, V. N., Nzei, N. and Igho, R. (2010). Impact of dredging on the water quality and macrobenthic invertebrate fauna of the Ikpoba River in Southern Nigeria. *Tropical Freshwater Biology*, 19(1): 59-78

Poznanska, M., Kabak, J., Wolnomiejski, N. and Kakareko, T. (2009) Shallow- water benthic macroinvertebrate community of the limnic part of a lowland Polish dam reservoir. *Limnologia*, 39:163-176.

Therschinge, G. (2001): Preliminary Keys for the identification of larvae of the Australian synthemisticdae, Gompho-Macromiidae, Pseudocorduliidae, Macromiidae and Austrocorduliidae (Odonata) Murray Darling freshwater Research Publications, Australia No.34, 90pp.

Tornwell, B., Sokol, E., Skelton, J. and Brown, B. L. (2015) Trends in stream biodiversity since the river continuum concept. *Diversity,* 7: 16-35.

Seiyaboh, E. I., Ogamba, E. N. and Utibe, D. I. (2013). Impact of dredging on the water quality of Igbedi Creek, Upper Nun River, Niger Delta, Nigeria. *Journal of Environment Science, Toxicology and Food Technology*, 7(5): 51-56

Valladares, F., Skillman, J. B. and Pearcy, R. D. (2002). Convergence in light capture among tropical forest under storey plants with contrasting crown architectures: a case study of morphological compensation. *American Journal of Botany,* 89:1275- 1284.

Zhang,, Y. Lui, L., Cheng, L., Cai, Y., Yin, H., Gao, J. and Gao, Y. (2014). Macroinvertbrate assemblages in streams and rivers of a highly developed region(Lake Taihu Basin, China). *Aquat Biol.*, 23:15- 28.