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Original Article

Macrobenthic invertebrate community structure and heavy metals concentrations in the crab, *Uca tangeri* in a Tidal Creek, Niger delta, Nigeria

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Abstract

Benthic macroinvertebrates and heavy metal contamination in *Uca tangeri* were studied to determine anthropogenic impact of metals on benthic fauna of the study area. Ten stations were sampled monthly along the main creek course for twenty four months. Multivariate analysis of community composition was used to determine community structure of the macroinvertebrates. Heavy metals concentrations in *Uca tangeri* were determined using Inductively Coupled Plasma Mass Spectrometry Agilent 7500c. The Nereid and Capitellid polychaetes contributed 35.2% to the benthic macroinvertebrates assemblage while *Uca tangeri* accounted for 34.1%. The abundance and diversity of macroinvertebrates were however, lower compared to earlier studies. Copper was found to be higher than the other measured metals in *Uca tangeri*. Target hazard quotient (THQ) revealed that consumers of the crab, *Uca tangeri* are potentially exposed to health hazard. Implication of the findings underscores the need for regular biomonitoring of the coastal ecosystem to forestall heavy metals contamination.

Keywords: bioaccumulation, diversity, estuary, health hazards, Niger delta, pollution

1. Introduction

Coastal waters are the most impacted of the marine ecosystem as a result of high anthropogenic inputs. Detection and control of these stressors are necessary for sustained ecosystem functions. The sedentary macroinvertebrates are better suited for detecting these changes. Their studies have also achieved a fundamental role in estuarine and marine impact assessment and management because the organisms usually exhibit well defined responses to environmental changes, especially those stressors which influence the sediment structure and composition (George, Abowei & Daka, 2009; McLusky & Elliott, 2004). Variations in their taxonomic richness and composition have been considered veritable tools for detecting alterations in aquatic ecosystems (Giorgio, Bonis, & Guida, 2016). These organisms are considered good indicators because most of them cannot migrate out of their habitat and they exhibit different tolerances to environmental stress (Kaboré, 2016). Due to the limited mobility, benthic organisms are more sensitive to local disturbance, and due to their permanence over seasons, they integrate the recent history of disturbances that might not be detected in the water column (Shogbanmu *et* al., 2016). Macrobenthic invertebrates are therefore, considered better indicators of fluctuations in aquatic ecosystems than the chemical and microbiological means which only give short-term changes (Gao, Zhang, Ding, Zhao & Meng, 2015). The macrobenthic fauna also occupy a very strategic position in the aquatic trophic relationship, especially in the detrital food chain. They interact with both the sediment and water and thus are key players in maintaining the integrity of the water body (Ogbeibu, Omoigberale, Ezenwa, Eziza & Igwe, 2014).

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Researches on water quality management aimed to evaluate the impacts of specific pollutants in aquatic ecosystems have been documented (Esenowo & Ugwumba, 2010; George, Abowei & Daka, 2009). Some biomonitoring tools are available for detecting and assessing aquatic pollution (Lewin, Czerniawska-Kusza, Szoszkiewicz, Ławniczak & Jusik, 2013). These include the monitoring of community composition to quantify changes in the abundance and diversity of species and tissue residual analysis to determine the bioavailability and bioaccumulation of contaminants such as heavy metals. When these procedures are combined and implemented in structural survey programs, they can identify the pollutants that are responsible for environmental degradation, identify sites at risk and prioritize their management to track the progress of remedial action (Álvarez-Cabria & Barquín, 2011).

Woji creek is an important aquatic ecosystem in the Niger Delta and is prone to pollution from numerous human activities within and outside the area. This aquatic body receives effluents from many industries, residential buildings and the main Port Harcourt abattoir sited along the bank. These wastewaters from domestic and industrial sources contain heavy metals of different types and in various concentrations which ultimately settle in the sediment of the creek. Heavy metals are important environmental pollutants with high level toxicity in the environment (Jaishankar, Mathew, Shah & Gowda, 2013; Jaishankar, Tseten, Anbalagan, Mathew, & Beeregowda, 2014). The bioaccumulation of heavy metals in water, sediment and periwinkle (*Tympanotonus fuscatus* var *radula*) from the Elechi Creek, Niger Delta has been documented by Davies, Allison & Uyi (2006). The most commonly found heavy metals in wastewater include arsenic, cadmium, chromium, copper, lead, nickel, and zinc, and their health risks have been associated with the consumption of some shellfish of contaminated waters (Alina *et al*., 2012). Some heavy metals have biotoxic effects in human biochemistry and physiology (Manju, 2015). According to ATSDR (2011), Cadmium (Cd) causes damage to the lungs, kidneys and bones, and it is a known human carcinogen while Copper (Cu) dust could result to undesirable conditions such as; nausea, headaches and diarrhea, as well as cause the irritations of the eyes, nose and mouth irritations may occur.

The levels of these heavy metals are usually higher in the sediment than in the water column. The benthic fauna are therefore, the most impacted. The fiddler crab, *Uca tangeri* is a common benthic macrofauna found in Woji creek. This crustacean is widely consumed by the locals and it forms a major delicacy in many homes. For decades, the consumption of this shellfish in the Niger Delta region of Nigeria has been both as delicacies and as staple food. Studies on water quality management using some of these macroinvertebrates in evaluating the impacts of specific pollutants in aquatic environments have been reported (Chinedu & Chukwuemeka, 2018; Esenowo & Ugwumba, 2010; George, Abowei & Daka, 2009). The potential risk of elevated heavy metal levels to human health in the Niger Delta region of Nigeria has been documented by Olawoyin, Oyewole & Grayson (2012) who reported levels of Lead (Pb) and Chromium (Cr) with values capable of causing cancer. However, specific studies on the health hazard associated with the consumption of the shellfish like *Uca tangeri* in this region is lacking. This study aims to use the community structure of benthic macroinvertebrates to assess the health status of Woji creek and potential human health risk associated with the consumption of *Uca tangeri* due to heavy metals pollution of the creek.

2. Materials and Method

2.1 Study Area

The Niger Delta is fan-shaped, geopolitical region with a landmass of about 70,000 square kilometer and located in the south-southern part of Nigeria. The area is a sedimentary environment formed from sediment deposited as the estuarine water loses energy while draining into the Atlantic Ocean. A major river, the Niger River forms a confluence with Benue River in the central part of Nigeria, and the two rivers, through network of distributaries, drain into the Atlantic Ocean. Its ecology is characterized by a very large floodplain created by the deposition and accumulation of sediments washed down from the Benue and Niger rivers (Chinedu & Chukwuemeka, 2018).

Woji creek and the upper reaches of the Bonny River estuary located between 7° 3’ N and 7° 1’ N and 4° 48’ E and 4° 52’ E (Figure 1) are part of the distributaries of the Niger Delta. The area is a typical estuarine tidal water zone with very little fresh water input but extensive tidal mangrove swamps. It is strategically located southwestern flanks of Port Harcourt and Okirika of Rivers State. This aquatic ecosystem is bounded by thick mangrove forest dominated by *Rhizophora* species interspersed by White mangrove (*Avicennia germinans*) and *Nypa fructicans*, and receives effluent discharges from several industries and main abattoir sited on its bank. The study area is located in a typical rainforest zone with two main hydrological seasons, wet and dry seasons. According to Edokpayi and Nkwoji (2007), rainfall influences both the hydrochemistry and benthic fauna assemblage of tropical waters. This forms the bases for summarizing the results of this study into the two seasons. The period between November and April is described as the dry months while May to October are rainy months. Ten non-random sampling stations were selected along the main creek course (Table 1) based on accessibility and proximity gradient from expected pollution sources. The stations were marked with the aid of Global Positioning System (GPS) (Magellan SporTrak GPS receiver) coordinates and visual notes of permanent and semi-permanent structures were used in marking sampling locations.

2.2 Collection and analysis of samples

2.2.1 Collection and analysis of benthic macroinvertebrates samples

Benthic samples were collected monthly between October, 2012 and September, 2014 at each study station (approximately 600 m apart) with a 0.25m^2 modified Van-Veen grab in the subtidal area of the study site at depth of about 2 m. Composite samples of three grab hauls were taken from an anchored motorized boat and sieved *in situ* through a 0.5 mm sieve according to Nkwoji, Yakub, Abiodun and Bello (2016). Materials retained on the sieve were preserved in 10% formalin and transported to a standard laboratory for sorting of clean samples. Identification and classification were conducted using relevant guides (Easton, Liz, & Ange, 2012; Mike *et al*., 2005;

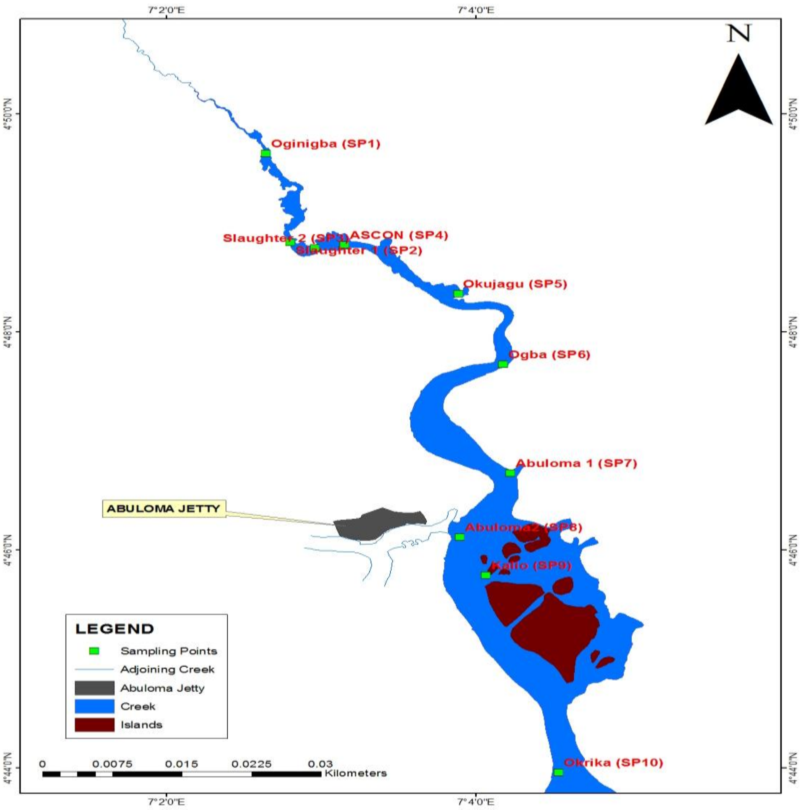

Figure 1. Map of Woji Creek and Bonny Estuary showing the sampling stations

Table 1. Sampling stations in Woji Creek and Bonny Estuary and their coordinates

Station	Location	Coordinates
SP1	Oginigba	04º 82.729’N 007º 04.403’E
SP2	Slaughter 1	04º81.353’N 007^{O} 04.666’E
SP3	Slaughter 2	04º 81.342’N 007º 04.850’E
SP4	ASCON	04º 81.314’N 007º 05.115’E
SP5	Okujagu	04º 80.544’N 007º 06.487’E
SP6	Ogba	04º79.411’N 007º 07.200’E
SP7	Abuloma1	04º 77.856’N 007º 07.042’E
SP8	Abuloma2	04º 76.897’N 007º 06.395’E
SP9	Kalo	04º 74.605’N 007º 07.653’E
SP10	Okrika	04º 73.222’N 007º 07.495’E

Yankson & Kendall, 2001). The sieved sediment samples (50 grams wet weight) from each station were stored in an aluminum container and labeled for heavy metals analysis.

2.2.2 Statistical analysis

The statistical package for social sciences (SPSS) 11.0 Windows application and the Microsoft Excel were used for the data analyses. The diversity indices such as Margalef’s, Shannon–Wiener and Simpson’s, and Equitability indices were computed using the PAST statistical program following standard methods adopted by Ogbeibu (2005). The diversity indices were used to identify the dominant fauna of both ecological and economical relevance that would form the basis for further analysis.

2.2.3 Collection and analysis of *Uca tangeri* for heavy metal

Having established its abundance, ten mature samples of the African fiddler crabs, *Uca tangeri* of approximate carapace length of 3cm were further handpicked from the mud tidal flats at each sampling stations at low tide for heavy metals (Mn, Fe, Ni, Cu, Zn, Cd, As and Pb) analysis. The samples were properly cleaned with distilled water to remove debris and dried in an oven at 60 0C to constant weight. The dried sample was homogenized using a domestic blender and 0.5 g of the homogenate was placed in Peflon tubes. 4 ml of a mixture of HNO_3 and H_2O_2 (1:3) were added and the reactor was covered and pre-digested overnight. The pre-digested samples were later subjected to Microwave digestion according to the procedure of USEPA (2009). An Agilent 7500c Inductively Coupled Plasma-Mass Spectrometry (ICPMS). (Agilent Technologies, Tokyo, Japan) was used for heavy metals determination. The quality of procedure was checked using Certified Reference Materials (CRMs) for biological tissues (DORM-3) (NRC, Canada)

2.2.4 Bioaccumulation Factors in *Uca tangeri*

The sediments were air-dried for 21 days under room temperature, disaggregated and sieved through a 200 µm-mesh size. The sieved samples were homogenized in a porcelain mortar and re-sieved. 0.25 g of the samples was placed in Teflon tubes and 5 ml aqua regia (HCl: HNO_3 in a ratio of 3:1) added for digestion according to Rahman, Asaduzzaman and Naidu (2013). The metal content of the digest was determined by Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) (Dussubieux & Van Zelst, 2004).

The biota-sediment accumulation factor (BSAF) was used to estimate the heavy metal accumulation in the crab tissues from that of the associated sediment. The BSAF was calculated as the ratio of the concentration of heavy metal in animal tissue to the concentration of heavy metals in the sediment following methods described by Franklin, Yap and Ahmed (2010) and Shirneshan and Riyahi (2012). The BSAF is an uptake factor and depends on the assumption that the concentration of a chemical in the tissue of biota is directly proportional to the concentration in the ambient sediment. This assumption may not apply if the uptake or depuration of the chemical concerned is well regulated or excreted. The metals concentration in *Uca tangeri* was expressed in mg/kg and the total metal content in sediment in mg/kg.

$$BSAF = \frac{HM\ concentration\ in\ animal\ tissue}{HM\ concentration\ in\ sediment}$$

2.2.5 Evaluation of public health risk associated with consumption of *Uca tangeri*

The public health risk associated with consumption of edible biota (*Uca tangeri*) collected from the study area was evaluated by using the Estimated daily intake (EDI) (Zhuang, Li, McBride, Zou, & Wang, 2013) to determine the Target Hazard Quotient (THQ) whose bench mark is 1 (Mansouri, 2015). The value of EDI was calculated by the method of Amir *et al*. (2015) as follows:

$$EDI = \frac{Uca\ tangeri\ intake\ \left(\frac{kg}{day}\right) x\ Heavy\ metal\ content\ in\ Uca\ tangeri (\mu g/kg)}{Average\ individual\ weight (kg)}$$

The methodology for estimation of THQ although does not provide a quantitative estimate on the probability of an exposed population experiencing a reverse health effect, but it offers an indication of the risk level due to pollutant exposure (US EPA, 2000; Storelli, 2008). Target Hazard Quotient is given by:

$$THQ = \frac{EDI}{RfDo}$$

where *EDI* is the estimated daily intake and *RfDo* is the oral reference dose. RfDo is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime (US-EPA, 2009).

3. Results

3.1 Community structure of benthic macroinvertebrates

The macrobenthic invertebrates of the study area were represented by 1644 individuals, comprising of 3 phyla, 5 Classes, 22 families and 28 species. The Phylum Annelida dominated the macroinvertebrates assemblage while Arthropoda contributed least (Figure 2). The African fiddler crab, *Uca tangeri* contributed 90% of the total number of individuals in the Phylum Arthropoda (Figure 2). The highest number of individuals (290) was samples at Station 8 while the least number (78) was sampled at Station 3 (Table 2). Result of diversity indices of the benthic macroinvertebrates is shown in Table 2. Both the species and individual abundance were higher in the dry than in the wet season. This could be attributed to both the reduced turbulence of the water body and decrease in the influx of land-based pollutants associated run-offs. It was also observed that the sampling stations 1-3 recorded lower abundance and diversity of the benthic macroinvertebrates compared to the other sampling stations. These stations have higher human impacts including slaughter abattoirs.

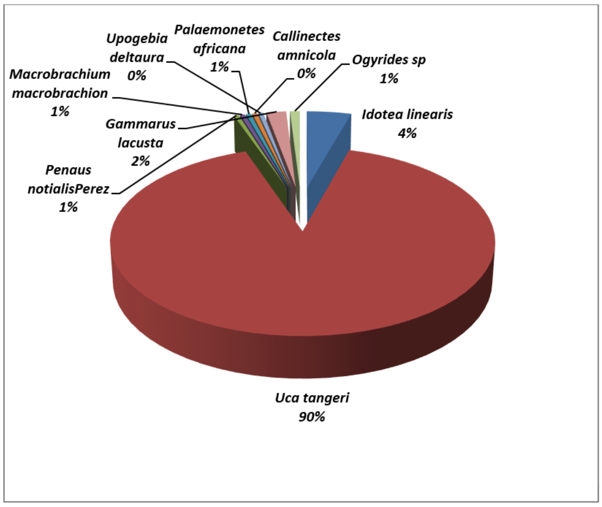

Figure 2. Species abundance in the phylum Arthropoda in Woji Creek and Bonny Estuary

3.2 Heavy metals concentration in *Uca tangeri*

The mean total concentration of heavy metals (Mn, Fe, Ni, Cu, Zn, As, Cd and Pb) in whole tissue homogenates of *U. tangeri* are presented in Figures 3-8. The results showed that Iron with a mean total of 1,625.43mg/kg was the most abundant heavy metal during the period of study while Lead and Cadmium recorded the least in abundance.

Table 2. Diversity indices of benthic macroinvertebrates in Woji Creek and Bonny Estuary

Diversity Indices	Station 1		Station 2		Station 3		Station 4		Station 5	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Species S	3	10	5	12	8	11	12	14	15	18
Individual N	20	102	26	136	32	46	66	120	57	77
Shannon Hs	0.41	0.72	0.53	0.65	0.76	0.90	0.64	0.70	1.09	1.17
Margalef's d	0.67	1.95	1,23	2.24	2.02	2.61	2.63	2.72	3.47	3.91
Equitability j	0.85	0.72	0.75	0.61	0.85	0.87	0.59	0.61	0.93	0.93
Dominance C	0.45	0.27	0.35	0.29	0.19	0.15	0.39	0.32	0.08	0.07
Diversity Indices	Station 6		Station 7		Station 8		Station 9		Station 10	
	Wet	Dry	Wet	Dry	Wet	Wet	Dry	Wet	Dry	Wet
Species S	11	15	8	14	10	11	15	8	14	10
Individual N	79	98	46	132	96	79	98	46	132	96
Shannon Hs	0.79	1.05	0.38	0.57	0.76	0.79	1.05	0.38	0.57	0.76
Margalef's d	2.29	3.06	1.83	2.66	1.97	2.29	3.06	1.83	2.66	1.97
Equitability j	0.76	0.89	0.42	0.50	0.76	0.76	0.89	0.42	0.50	0.76
Dominance C	0.22	0.11	0.65	0.37	0.22	0.22	0.11	0.65	0.37	0.22

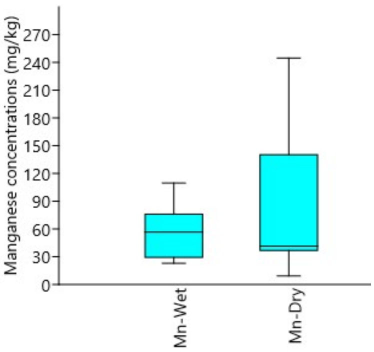

Figure 3. Mean concentration of manganese (Mn) in *Uca tangeri*

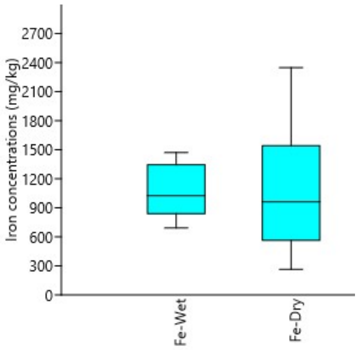

Figure 4. Mean concentration of iron (Fe) in *Uca tangeri*

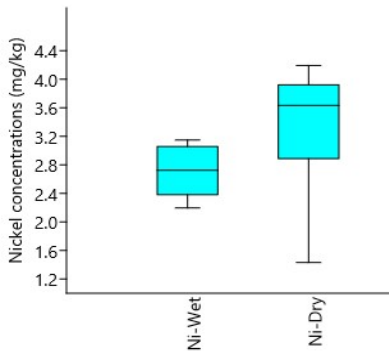

Figure 5. Mean concentration of nickel (Ni) in *Uca tangeri*

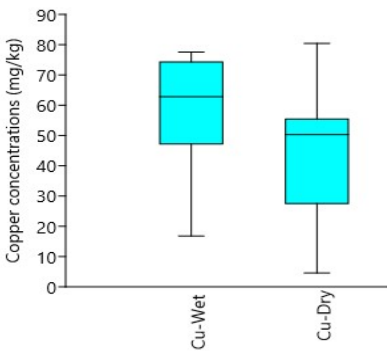

Figure 6. Mean concentration of copper (Cu) in *Uca tangeri*

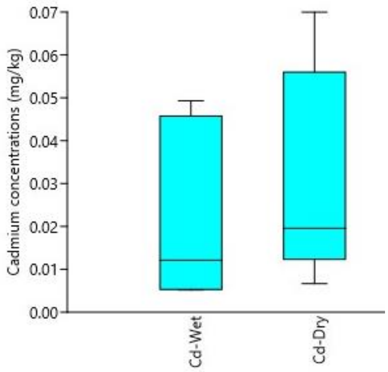

Figure 7. Mean concentration of cadmium (Cd) in *Uca tangeri*

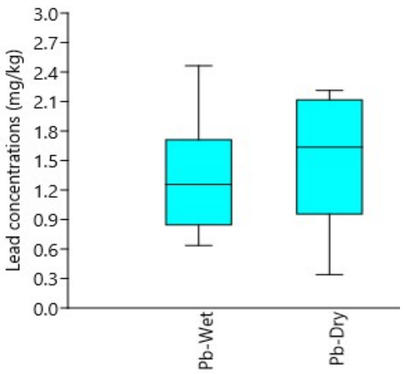

Figure 8. Mean concentration of lead (Pb) in *Uca tangeri*

3.3 Biota-sediment Accumulation Factor (BSAF) and Target Hazard Quotient (THQ)

The concentration of heavy metals in *Uca tangeri* was lower than in sediment except for Copper during the wet season. However, the computed bio-sediment accumulation factor (BSAF) indicated high level of Cd, Cu and Ni load in *Uca tangeri* during the period of study. The BSAF revealed heavy metals accumulation in the crab, *Uca tangeri* for Cd (24.81) and Ni (4.66) during the dry season, and Cu (5.63) during the wet season (Tables 3). The results of Target Hazard Quotient (THQ) which points to the tendency of the exposed

Table 3. Heavy metal bioaccumulation factor in *Uca tangeri*

Heavy Metals	BSAF in wet season	BSAF in dry season
Cr	0.11	0.06
Mn	0.663	0.67
Fe	0.07	0.06
Co	0.13	0.52
Ni	0.61	4.66
Cu	5.63	2.11
Zn	0.93	0.04
As	0.41	0.01
Cd	1.11	24.81
Pb	0.17	0.13

population to suffer health consequences revealed values above 1 for Mn in the wet (1.42) and dry season (2.36) and Cu (1.14) in the dry season (Table 4). Values of the oral reference doses (RfDo) for some heavy metals were adapted from the works of Chauhan and Chauhan (2014).

4. Discussion

The dominance of the Annelida in the study area is in consonance with the report of George, Abowei, and Daka (2009). Investigation of species abundance and richness in the study area also revealed the presence of organic pollution indicators, *Capitella capitata* and *Nereis diversicolor*. According to Edokpayi, and Nkwoji (2017), the abundance of these polychaetous Annelids was indicative of organic pollution. Furthermore, low species diversity indicated by lower values for the Shannon-Wiener index are recorded in this study compared to previous studies in that region (George, Abowei, & Daka, 2009; Hart & Zabbey, 2005; Nkwoji, Yakub, Abiodun, & Bello, 2016). Hart and Zabbey (2005) stated that increase and decrease in faunal abundance might be attributed to larval settlement, migration, reduction in interspecific competition and post recruitment mortality. However, the presence of pollution tolerant species and the general low diversity and abundance of the benthic macroinvertebrates indicate that the study area is anthropogenically impacted.

Although the concentrations of heavy metals in *Uca tangeri* were lower than those found in sediment, the value (>1) of the uptake factor (BSAF) in some of the heavy metals indicates high tendency of bioaccumulation of the metals in the tissues of the biota. Target Harzard Quotient value <1 indicates that the exposed population is unlikely to experience obviously adverse effects while a value >1 suggests the potential for non-carcinogenic health effects, with an increasing probability as the value increases (Zhuang, Li, McBride, Zou, & Wang, 2013). The THQ values in this study for Mn and Cu (>1) therefore, suggest that the exposed population might likely suffer from non-carcinogenic health effect due to the consumption of Mn and Cu contaminated *Uca tangeri*. This pose great health risk which may either be carcinogenic or non-carcinogenic effects (Wang, Sato, Xing, & Tao, 2005) as the African fiddler crab is widely consumed by the local communities

5. Conclusions

Anthropogenic influences and seasonal run-offs introduce pollutants, including heavy metals into the coastal waters resulting in loss of biodiversity as evidenced in this study. Sampling stations with obvious anthropogenic activities such as slaughter abattoirs recorded very low diversity and abundance of the benthic macroinvetebratess. The general lower diversity of the benthic macroinvertebrates during the rainy season is an indication of the possible negative impacts of the run-offs from rain could cause on the macrobenthic community. The sedentary nature of the benthic macroinvertebrates makes them most vulnerable. When the uptake of some of these heavy metals by some edible shellfish is high, it poses potential health risk to the consumers. In this study, although the concentrations of most of the heavy metals analysed in the crab *Uca tangeri* may not constitute direct threat to health except for copper, the values of the uptake factor and the target hazards quotient in some of the metals in the edible crab is significantly high and therefore, pose potential health risk as *Uca tangeri* is highly consumed by the local coastal communities. Concerted efforts should be made through biomonitoring and sustainable policies, to control the introduction of wastes that are laden with heavy metals into our coastal ecosystem as they pose great health risks to humans.

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Table 4. Computed estimated daily intake (EDI) and target hazard quotient (THQ) of heavy metals in *Uca tangeri* from Woji creek and Bonny Estuary

		Cr	Mn	Fe	Ni	Cu	Zn	As	Cd	Pb
EDI	WET	0.001	0.020	0.382	0.001	0.046	0.009	0.001	0.000	0.000
	DRY	0.001	0.036	0.431	0.001	0.018	0.009	0.001	0.000	0.001
THQ	WET	0.001	1.415	0.546	0.049	1.140	0.030	0.000	0.009	0.119
	DRY	0.001	2.357	0.589	0.064	0.447	0.030	0.000	0.011	0.145

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