Total Hydrocarbon and Heavy Metal Concentrations in Body Parts of Fiddler Crab (*Uca tangeri*) (*Ocipodidae*) in the Niger Delta, Nigeria

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Abstract

This study is based on the hypothesis that the burrowing habit of fiddler crabs in polluted environment will predispose them to heavy metal contamination. The study was carried out in Eagle Island, a mangrove community. Thirty fiddler crabs (*Uca tangeri*) were captured by hand and butchered into parts and oven dried at 70°C for 48 hours. They were sent to laboratory to determine total hydrocarbon content (THC), Cadmium (Cd), Zinc (Zn) and Lead (Pb) concentrations. The laboratory procedure involved measurement by spectrophotometric method using the HACH DR 890 colorimeter (wavelength 420 nm) for heavy metals and microwave accelerated reaction system (MARS Xpress, North Carolina) for THC. The result indicate that there was no significant difference in THC and heavy metal concentration between crab parts (*F*<sub>4,48</sub> = 0.32, *P*=0.925). However, Zinc had the highest concentration in the crab parts followed by Lead and Cadmium. Zinc was the highest in body tissue (83.57±17.04 mg/L) followed by intestine (70.59±1.54 mg/L) and ventral shell (67.44±1.1) mg/L. Lead was highest in ventral shell (44.5±34.5) mg/L while Cadmium was highest in carapace (10.02±3.99) mg/L. The order of concentration in the body parts of *U. tangeri* is Zn>Pb>Cd>THC. THC and Lead were higher in males than in females while Zinc and Cadmium were higher in females. External parts have higher THC, Cd and Pb while internal parts have higher Zn. This result indicates that heavy metals bioaccumulated in fiddler crabs, which can get biomagnified in humans if consumed.

Keywords *Uca tangeri*; *Rhizophora*; Heavy metals; Bioaccumulation; Niger Delta; Total hydrocarbons

Background

Crabs play unique role in mangrove forest and other coastal systems because they are ecosystem engineers (Nobbs and Blamires, 2015). Crabs cause zonation of mangrove forests by selectively consuming propagules and burying seedlings in holes along the coastlines (Cannicci et al., 2008). The random distribution of the seedlings influences the pattern of mangrove growth, which may result to either a scantly or thick forest. Spatial distribution of the seedlings results to gaps in mangrove forest. Seed-burying behavior of crabs expedites the growth of mangrove seeds. *Rhizophora* seedlings have torpedo shape and a pointed tip which pierces the soil after detachment from the tree to enable speedy growth (Ismaiel et al., 2010). However, this situation does not always occur especially when seeds drop on hard soil or on water surface during high tide, the crabs therefore comes to the rescue by burying the seeds. Amongst the three mangrove species (i.e. red, black and white), the red mangroves have the largest seed size, which help them to settle on the soil for speedy growth without being flushed out by tidal current. There are also tree climbing crabs that feed on the seeds and leaves of mangrove trees (Cumberlidge et al., 2005). The West African red mangrove crabs (*Goniopsis pelii*) are known to climb mangrove trees to forage while other crabs are ground dwellers which spend more time inside or outside their burrows (e.g. *Uca tangeri*). There are different crab species in the coastal areas of the Niger Delta, but the two most common ground-dwelling crab species are the West African Red mangrove crabs (*Goniopsis pelii*) and the Fiddler crab (*Uca tangeri*).

Fiddler crabs are of the family Ocypodidae and subfamily Ucinae (Callander et al., 2013). The male and female have sexual dimorphism and exhibit size differences in their claw. They are mostly found along sea beaches, brackish inter tidal mud flats, lagoon, coast and swamps. Their dominant presence in the Atlantic Ocean had made them to be called the West African fiddler crabs. Their name “fiddler crab” is derived from the habit of the males that plays with its large right claw as a fiddle (Levinton et al., 1995). The fiddler crabs are not a major food for...
people in this region, although very few persons eat them. They are rather a delicacy for fishes once they die. In some localities fishermen use the crabs as bait during fishing. They help to clean up the mud surface by feeding on fallen leaves (Olafsson et al., 2002) and practically carry litter away for burial in different parts of the swamp. This habit of burying litter inside the swamp accelerates the process of litter decomposition (Numbere and Camilo, 2017). 

*Uca tangeri* are very populous in most locations in the Niger Delta. In an area of about 4,000 m\(^2\) there are over 1000 *U. tangeri* spread across the swamp. This species are mostly dominant in human-disturbed area especially sand filled swamp environment. They have unique outer features that distinguish the male and females without reference to their internal biology. The right pincer of the male is larger than the left, whereas the females have small pincers for both arms (Holman et al., 2014). It is said that the large pincer is used during courtship to woo the females for mating (Crane, 1975; Kim et al., 2004). The pincers are also used as diggers to dig burrowers where the crab resides. Because of the size of their right pincers they also act as defenders of their territories and predators to other crabs (Takeda, 2010). It is believed and has been verified during field work that the waving of the pincers in the air means that they are inviting tidal currents. More studies are however needed to verify this observed behavior. However, other researchers believe the waving is for mate attraction (Backwell, 2018). The fiddler crabs are also a delicious delicacy for fishes e.g. tilapia, which makes them to be significant aspect of the food chain in the mangrove ecosystem. The problem is that their burrowing habit exposes them to contamination by pollutants in the soil. Pollutants are consumed indirectly from the soil during feeding or absorbed into their body while embedded in their holes. Their habit of burying litter in holes for it to decompose before consuming it facilitates this process. Their bodies act as a sink for some pollutant such as total hydrocarbons (THC) and heavy metals, which enter their digestive system and get absorbed into their shells. Direct or indirect consumption of fiddler crabs can lead to public health problems. I thus hypothesize that the burrowing habit of fiddler crabs in polluted environment will predispose them to contamination. The objective of the study therefore, are: (1) to determine the THC and heavy metal concentration in body parts of fiddle crabs; (2) to compare the THC and heavy metal concentration in male and female crabs; (3) To compare the relationship between THC and heavy metals in body parts of crabs and soils dug out by crabs from their burrows.

### 1 Materials and Methods

The study was conducted in a mangrove patch used for sand mining directly behind the Rivers State University at Eagle Island, Niger Delta (N 4º47.317’, E6º 58.593’) (Figure 1). The study area is abandoned sand mine connected to a river channel, which brings in mangrove seedlings at different stages of growth. The study area is a recipient of high rainfall because it is surrounded by rivers and is linked to the Atlantic Ocean. The soil is whitish to brown in color due to the presence of dredged sand. The soil is loose and muddy and cannot be molded into a circle. The pH of the soil is between 6~7. The area is partially submerged by water during high tide and becomes dry during low tides in a six hour cycle of tidal fluctuations. During low tides the crabs come all out to forage and during low tides they hide in their holes (Luppi et al., 2013).

#### 1.1 Description of study species

The fiddler crabs are the most dominant land crab in the area. They have large populations, which is over 3,000 in the entire study area. They are made up of a combination of dull red, black and white color. Their males and female can easily be distinguished by the pincers. The right pincers of the male is larger than the left, whereas the female have small pincers of equal sizes. The crabs have the habit of beating a fast retreat into their burrows when confronted (Jordão and Oliviera, 2001; Gruber et al., 2019). The males use the large pincers to invite the female during courtship. The pincers are also waved in the air to invite water during low tides. The males are generally bigger than the females (Johnson, 2003) (Figure 2). The male and female crabs can also be distinguished by the size of their ventral carapace. The male ventral carapace has a small triangular middle region while the females have a large semi circular middle region.
Figure 1 Map of study area at Eagle Island, Niger Delta, Nigeria

Figure 2 Fiddler crab (U. tangeri) showing (a) male, (b) female and (c) body parts of crabs captured at Eagle Island, Niger Delta, Nigeria

1.2 Sample collection

The crabs were captured inside their burrows after the inner holes were blocked with a stick that was used to pierce through the holes of the crabs (Sterman et al., 2019). In all forty crabs were captured by hand, and carefully placed in a perforated container. The crabs were sorted into males and females based on their external morphology, and their sizes were measured with a meter rule. The crabs were butchered into parts (carapace, ventral, intestine, pincers, gill, limb and body tissue) following the example of Devescovi and Lucu (1995) and put in polyethylene bags, placed in a cooler and sent to the laboratory for physicochemical analysis for total hydrocarbon content (THC), Zinc (Zn), Cadmium (Cd) and Lead (Pb). In the laboratory the body parts were placed in aluminium foil
and oven dried at 70°C for 48 hours to get rid of moisture. Metal concentration from the tissues was determined by following the procedures of Dhaneesh et al. (2012).

Ten soil samples each dug out by crabs from the burrows were collected randomly from three sites, and placed in a polyethylene bag and transported in a cooler to the laboratory for analysis for THC, Zn, Cd and Pb.

1.3 Laboratory analysis
1.3.1 Procedure of total hydrocarbon content analysis
It involved the use of spectrophotometric method using the HACH DR 890 calorimeter. The samples were crushed and 2 g of the crushed sample was weighed into a glass beaker and mil of hexane was added, and with the aid of a glass rod, the mixture was homogenized by stirring. Afterwards, the sample was filtered in a glass funnel packed with cotton wool, silica gel and anhydrous sodium sulphate. After this, 10 mil of the filtered organic extract was transferred into a 10 mil sample curvet and inserted into the calorimeter.

1.3.2 Heavy metal analysis
Aliquots of 0.25 g of air dried sediment samples were weighed into a Teflon inset of a microwave digestion vessel and 2 mL concentrated (90%) nitric acid (Sigma-Aldrich, Dorset, UK) were added. The metals were extracted using a microwave accelerated reaction system(MARS Xpress, CEM Corporation, Matthews, North Carolina) at 1500 W power (100%), ramped to 175°C in 5.5 min, held for 4.5 min, and allowed to cool down for 1 h. The cool digest solution was filtered through the Whatman 42 filter paper and made up to 100 mL in a volumetric flask by adding de-ionized water. All chemicals and reagents used were of analytical grade and of highest purity possible. Analytical blanks were prepared with each batch of the digestion set and analyzed (one blank for every set of 6 samples) in the same way as the samples.

1.4 Statistical analysis
To determine the significant difference of the concentration of THC and heavy metals in the body parts of the crabs an analysis of variance (ANOVA) was done. An ANOVA was used because there is replication of data, where N>2 (Logan, 2010). The data was first log transformed to ensure that they were normal and the variances were equal. To determine the relationship between THC and heavy metal in body parts of the crabs and soil, a Pearson’s correlation coefficient test was performed where the null hypothesis states that the correlation coefficient of THC and heavy metal concentration of soil and crab parts equals zero. Bar graphs were then used to illustrate the significance and difference in concentration in body parts and between male and female crabs. All analyses were done in R.

2 Results
2.1 THC and heavy metal concentration in body parts of fiddler crabs (Uca tangeri)
The result (Table 1; Figure 3) indicates that there is no significant difference in THC and heavy metal concentration between parts (F_{6, 49} = 0.32, P=0.925). However, there was a significant difference in the concentration of the THC and heavy metals (F_{3, 52} = 29.18, P= 0.001). Zinc has the highest overall concentration in the body parts of crabs (Uca tangeri) followed by Lead and Cadmium (Table 1). Similarly, Zinc concentration was highest in the body tissue (83.57±17.04) mg/L followed by intestine (70.59±1.54) mg/L and ventral shell (67.44±1.1) mg/L. This is in agreement with the results of FAO/WHO (2006) who revealed that Zinc concentration was the highest in fish gill, muscle and liver. Furthermore, another study indicated that claw tissue, gill and gut of Goniopsis pelii had high Zinc concentration (Numbere, 2019). The highest Lead concentration was recorded in ventral shell (44.5±34.5) mg/L followed by posterior carapace (17.01±7.00) mg/L and pincers (12.55±2.55) mg/L. Cadmium concentration was highest in carapace (10.02±3.99) mg/L followed by Gill (6.17±1.06) mg/L and pincers (4.71±2.53) mg/L. The order of concentration in the body parts of U. tangeri is Zn>Pb>Cd>THC. The range of Lead in most parts of the crab (i.e. 8.06–44.5) mg/L showed that it is above the international standards with the exception of the intestine, gill and body tissue. The total hydrocarbon content of the organs is below 1.0 mg/L, which may mean that they utilize THC better than Goniopsis pelii.
Table 1 Mean levels of total hydrocarbon content (THC) and heavy metals ± 1 SE in different body parts of crab (*Uca tangeri*) in Eagle Island, Niger Delta Nigeria

| Body parts   | THC      | Metals (mg/L) | Cadmium  | Lead    |
|--------------|----------|---------------|----------|---------|
| Carapace     | 0.08±0.0 b | 8.00±3.09 a  | 10.02±3.99 b | 17.01±7.00 b |
| Ventral shell| 0.07±0.01 b| 67.44±1.1 b   | 2.84±1.67 e | 44.5±34.5 e  |
| Intestine    | 0.02±0.0 b | 70.59±1.54 b | 2.58±0.76 e | 0.001±0.00 e |
| Pincers      | 0.06±0.0 b | 58.58±29.07 c| 4.71±2.53 e | 12.55±2.55 e |
| Gill         | 0.04±0.01 b| 59.96±1.11 c | 6.17±1.06 b | 0.001±0.00 e |
| Limb         | 0.39±0.32 a| 53.71±6.58 d | 1.45±0.29 e | 8.06±1.02 e  |
| Body tissue  | 0.08±0.01 b| 83.57±17.04 a| 2.13±0.98 e | 0.001±0.00 e |

Note: Different letters on column indicate significant differences (*p* < 0.05)

Figure 3 Concentration of some heavy metals (Cadmium, Lead and Zinc) and THC in different body parts of crab (*U. tangeri*) captured in Eagle Island, Niger Delta, Nigeria. Vertical lines show ±1 standard error of the mean.

2.1 THC and heavy metal concentration between male and female crab

The result (Table 2, Figure 4) indicates that there was no significant difference between male and female crab (*F*$_1$, 54 = 0.11, *P* = 0.74). Nevertheless, the concentration of THC and Lead was higher in males than in females while the concentration of Zinc and Cadmium was higher in females (Figure 4).

Table 2 Mean levels of total hydrocarbon content (THC) and heavy metals ± 1 SE in male and female crabs (*Uca tangeri*) in Eagle Island, Niger Delta Nigeria

| Sex     | THC    | Metals (mg/L) | Cadmium | Lead    |
|---------|--------|---------------|---------|---------|
| Male    | 0.15±0.09 a | 52.11±8.55 b | 2.96±0.97 e | 23.46±12.07 e |
| Female  | 0.06±0.01 a | 62.59±11.72 a| 5.57±1.55 b | 0.001±0.00 b  |

Note: Different letters on column indicate significant differences (*p* < 0.05)

2.2 THC and heavy metal concentration in internal and external body parts of crab

There is no significant difference in THC and heavy metal concentration in the internal and external parts of the crabs (*F*$_1$, 54 = 0.006, *P* = 0.936, Figure 5, Table 3). However, external parts have higher concentration of THC, Cd and Pb while internal parts have higher Zn concentration.

2.3 Comparison of THC and heavy metal concentrations in burrow soil and crab parts

The result indicate the correlation between concentrations of THC and heavy metals in soil and body parts of crab was negative, meaning that there was a weak correlation (*r* = -0.07, *t*$_{54}$ = -0.55, *P* > 0.05; Figure 6). Comparison of results in Table 1 and Table 4 shows that heavy metal concentration was higher in crab than in burrow soil. This is because the range of Zinc in crab is higher (8.00–83.57 mg/L) than the range in soil (1.13–3.5 mg/L). The range of Cadmium in crab is higher (1.45–10.02 mg/L) than the range in soil (0.001–0.44 mg/L). Similarly, the range of
Lead in crab is higher (0.001–44.5 mg/L) than the range in soil (0.12–27.46 mg/L). In contrast, the range of THC was higher in soil (2.37–10.31 mg/L) than in crab (0.02–0.39 mg/L). This result is an evidence that there was an active bioaccumulation of heavy metals from soil to the body of crabs.

Figure 4 Mean concentration of THC and heavy metals in males and female crabs captured at Eagle Island, Niger Delta, Nigeria

Figure 5 Mean concentration of THC and heavy metals in internal and external parts of crabs captured at Eagle Island, Niger Delta, Nigeria

Table 3 Mean levels of total hydrocarbon content (THC) and heavy metals ± 1 SE in internal and external parts of crabs (Uca tangeri) in Eagle Island, Niger Delta Nigeria

| Area          | Metals (mg/L) | THC         | Zinc         | Cadmium     | Lead         |
|---------------|---------------|-------------|--------------|-------------|--------------|
|               | Internal parts| 1.045±0.01 \( ^a \) | 71.24±6.23 \( ^a \) | 3.62±0.91 \( ^a \) | 1.10±0.00 \( ^a \) |
|               | External parts| 1.15±0.10 \( ^a \) | 46.93±10.38 \( ^a \) | 4.75±1.55 \( ^a \) | 20.53±10.85 \( ^a \) |

Note: Different letters on column indicate significant differences (\(p < 0.05\))

Figure 6 Graph of correlation between pollutant (THC, Cd, Pb and Zn) concentration in soil and crab at Eagle Island, Niger Delta Nigeria. Soil concentration is inversely proportional to crab concentration

Table 4 Physicochemical parameters of soil dug out by crabs (Uca tangeri) from their burrows at Eagle Island, Niger Delta, Nigeria

| Parameters | Site 1        | Site 2        | Site 3        |
|------------|---------------|---------------|---------------|
| pH         | 6.3±1.14      | 5.9±1.23      | 6.5±1.14      |
| Temperature (°C) | 26.4±0.13      | 29.8±0.11      | 27.5±0.16      |
| THC        | 10.31±2.60    | 9.10±0.01     | 2.37±0.11     |
| Zinc (mg/L) | 3.5±0.25      | 1.13±0.47     | 1.27±0.43     |
| Cadmium (mg/L) | 0.44±0.01    | 0.42±0.01     | 0.001±0.00    |
| Lead (mg/L) | 27.46±3.53    | 8.29±1.05     | 0.12±0.01     |
3 Discussion

3.1 THC and heavy metal concentration in body parts of fiddler crab (Uca tangeri)
Crabs are ground feeders and burrowers, which predispose them to having contact with the soil. They consume particles of metals while feeding and also live inside burrows which are filled daily with water during high tide. *Uca tangeri* has low bioaccumulation of THC and heavy metals as compared to *Goniopsis pelii*. This might be as a result of low ground pollution in the study site (Table 4). The area is a wharf where boat transport people to and fro from the neighboring community. This activity result to the emission of engine oil into the aquatic environment. People also dump waste into the adjoining river. However, the pollution level is low because of low industrial activities. This is the reason why the THC levels in the crab and soil samples were low. Another factor that contributes to low THC and heavy metal concentration is regular tidal flushing of the soil. During high tide water rushes ashore and clean up the swamp of its waste products and oil films. The fiddler crab burrow is therefore constantly being filled with tidal water, which washes away any pollutants. *Uca tangeri* habit of feeding on plant and animal (e.g. fingerlings) matter washed ashore by tides expose them to pollutants (Table 1). Zinc concentration was the highest which is in line with the result of previous study by Numbere (2019). Soils and water samples collected from the study area have high Zinc concentration due to high background level of this metal. There is possibly a high Zinc concentration in the parent rock, which thousands of years ago had weathered into soil particles. A worrisome finding is the high Lead content (8~45 mg/L) in the outer part of the crabs (Table 1), which is far above the international standards of < 1.0 mg/L for food substances. This can get biomagnified in humans and animals that consume them.

3.2 THC and heavy metal concentration between male and female crab
The male and female fiddler crabs are not too different in size, apart from the heavy and large projected right pincers of the male. The bioaccumulation of THC and heavy metal cuts across both sexes as shown in Table 2. This means both sexes are equally exposed to pollutants in the study environment. However, the high amount of Lead in the body of the male crab (23.46±12.07) mg/L as compared to the female (0.001±0.00) mg/L shows that the males are more susceptible to this poisonous metal. This is probably because of their exploratory behavior of digging burrows and incising litter materials with their huge right claw.

3.3 THC and heavy metal concentration in internal and external parts of crab
The result of this study is in line with previous studies on *G. pelii* that show that external parts of crabs have more bioaccumulation of THC and heavy metals (Numbere, 2019). This is because the external parts have more contact with the environment as compared to the internal parts. The burrowing habit of the crabs exposes their bodies to contamination from soil pollutants. Apart from Zinc that is low all other metals were high in the external body parts of the crabs (Table 3). More Zinc is absorbed via food because of high background level. Heavy metals consumed through food are transmitted to the shell because it is the store house for trace elements (e.g. Calcium), which helps to build and strengthen the outer shell against environmental pressure. The behavior of the crab in feeding off from the mud exposes them to harmful metals and crude oil deposits from spilled pipelines or engine oil from marine craft.

3.4 Comparison of THC and heavy metal concentrations in burrow soil and crab parts
The increase in heavy metals in the body of crabs as compared to the soil level shows an evidence of biomagnification. This implies that the heavy metal biomagnified in the body of the crabs. This is worrisome because as it goes up the food chain the concentration will continue to increase and become more toxic to humans. However, the THC was higher in the soil than in the body of the crab, this means there was less bioaccumulation of THC in crabs. This might be that the crab digestive system was able to break down some hydrocarbons or that the soil level was below the threshold of absorption by the crabs. Field observation indicates that there was low industrial activities and thus less oiling in the study area where the crabs were captured.

4 Conclusion and Recommendation
Fiddler crabs are dominant crab species in the coastal mangrove forest of the Niger Delta. They are an important aspect of the mangrove and wetland ecology because of their role in redistributing and burying of seeds, which
facilitate growth. They are also useful in accelerating decomposition by incising and burying mangrove leaves in burrows to help reduce the tannin content before consumption. They also clean the surface of the swamp by feeding on leaves and dead organisms (e.g. fingerlings) brought in by tidal currents. However, apart from their ecosystem services they can also become an avenue for contaminating humans. Although U tangeri are not directly eaten by people in the area, the bioaccumulation of heavy metals in their bodies can move up the food chain to contaminate other organisms. There is therefore a need for bio-monitoring of the environment using soil and crab samples to check if the contamination level had exceeded the standard limit. This is to prevent food poisoning from the consumption of sea food such as periwinkle, fish and mussels found in the same environment.

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