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Ecological Assessment of Heavy Metal Contamination of *Tympanotonus fuscatus* in Iko River Basin

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ABSTRACT

Background: *Ecological assessment of heavy metal contamination of Tympanotonus fuscatus in Iko River Basin was investigated for a period of twelve (12) months between September 2022 – August, 2023 with aim of understanding the ecological status and the safety of consuming the mangrove periwinkle (Tympanotonus fuscatus) obtained from the Estuary.*

Methodology: *Samples of T. fuscatus were bought from landings of artisanal fisheries in Iko River Basin on a monthly* ***basis*** *for a period of 12 months. The samples were placed immediately in poly-ethylene bags, put into an isolated container of polystyrene icebox, and then brought to the laboratory prior to laboratory analysis. In the laboratory standard analytical procedures were adhered to in the preparation of samples prior to heavy metal determination using Perkin-Elmer Analysts 800 Atomic Absorption Spectrophotometer (AAS).*

Results: *From the results it was found out that the mean concentration of heavy metal throughout the study duration followed the trend Fe > Zn > Cr > Mg > Cu > Pb > Ni > Cd for the dry season while a different trend Fe > Zn Pb >> Mg > Ni >> Cu > Cr > Cd was observed during the wet season. Amongst the metals studied, seasonal variation was observed for zinc. The dominance of Fe and Zn throughout the study duration was attributed to their abundance in the earth's crust. Correlation analysis showed a strong positive relationship between metal pairs in the dry season which portends that an increase in the concentration of one metal mandates a corresponding increase in the other while a negative correlation was observed between metals pairs in the wet season which signifies an inverse relationship. The hierarchical cluster dendrogram delineated the metals into four (4) cluster groups in the dry season and three (3) cluster groups in the wet season based on concentration gradient and source of contamination.*

Conclusion: *However, the results of the findings showed that the concentration of heavy metal in the tissue of the studied species fell within the WHO/FAO recommended threshold limit for safe consumption of aquatic seafood. By mitigating the sources of contamination and implementing effective conservation strategies, we can safeguard T. fuscatus and preserve the ecological balance of the vital estuarine environments they inhabit through collaborative efforts from regulatory bodies, industries, and local communities.*

Keywords: *Ecological Assessment, Heavy Metal, Contamination, Tympanotonus fuscatus, Iko River Basin*

1. Introduction

The mangrove periwinkle, scientifically known as *Tympanotonus fuscatus*, is a critical component of estuarine ecosystems. These small gastropod mollusks play a vital role in maintaining ecological balance by participating in nutrient cycling and serving as a food source for various organisms. However, the contamination of *T. fuscatus* by heavy metals poses a significant threat to both the species and the delicate coastal environments they inhabit (21; 23).

Heavy metal contamination in *T. fuscatus* primarily arises from anthropogenic activities such as industrial discharges, agricultural runoff, and improper waste disposal. These activities introduce metals like mercury, lead, cadmium, and zinc into the estuarine habitats, where these periwinkles thrive. The metals then accumulate in the water and sediment, eventually finding their way into the tissues of *T. fuscatus* through bioaccumulation (3; 4; 5; 6; 7; 8; 10; 21; 25).

T. fuscatus, being filter feeders, obtain nutrients by filtering particles from the water. Unfortunately, this filtering process also makes them susceptible to accumulating heavy metals present in the water column. Additionally, the sediments in their habitats serve as sinks for these metals, contributing to their gradual uptake by the periwinkles. As the metals accumulate in the tissues over time, the potential for adverse effects on both individual organisms and the entire ecosystem increases.

The contamination of *T. fuscatus* by heavy metals can result in various health issues for the species. Elevated levels of metals can lead to physiological stress, impaired reproductive success, and compromised immune function (23)). Furthermore, the accumulation of heavy metals in their tissues may affect the quality of the periwinkles as a food source for higher trophic levels, thereby impacting the entire estuarine food web. The contamination of *T. fuscatus* by heavy metals extends beyond the individual level, influencing the health and dynamics of the entire estuarine ecosystem. As a keystone species, the periwinkle's decline can disrupt nutrient cycling and alter the composition of the community. Moreover, the potential transfer of accumulated metals up the food chain poses risks to other organisms, including humans, who may consume contaminated seafood (16; 22).

Addressing the contamination of *T. fuscatus* requires a comprehensive approach that involves both regulatory measures and community awareness. Efforts should focus on reducing industrial discharges, implementing proper waste management practices, and promoting sustainable agriculture to minimize runoff. Additionally, ongoing monitoring programs are essential to assess the extent of contamination and track changes in the health of *T. fuscatus* populations.

The contamination of *T. fuscatus* by heavy metals is a critical environmental issue with far-reaching consequences. Protecting these estuarine ecosystems demands collaborative efforts from regulatory bodies, industries, and local communities. By mitigating the sources of contamination and implementing effective conservation strategies, we can safeguard *T. fuscatus* and preserve the ecological balance of the vital estuarine environments they inhabit.

2. Materials and Methods

2.1 The Study Area

Iko River estuary is in Eastern Obolo Local Government Area, Akwa Ibom State, in the Niger Delta region, Nigeria. The area lies within latitude 4°0'30' N and longitude 7°40' E (Fig. 1) (15; 19; 26). The river has a shallow depth ranging from 1.0 m to 7.0 m at flood and ebb tide. Iko River takes its rise from Qua Iboe River catchments and drains directly into the Atlantic Ocean at the Bight of Bony (15). The adjoining Creeks, channels, and tributaries from the Iko River estuary are significant in the provision of suitable breeding sites for the diverse aquatic resources that abound in the area. The shoreline of the Iko River estuary is fringed with mangrove and nipa vegetation, tidal mud flats and pneumatophores of *Avicenia* exposed during low tide. The macrophytes are composed of the native red mangrove; *Rhizophora racemosa*, *R. harrizonii*, *R. Mangle*, black mangrove (*Avicenia africana*), and *Laguncularia racemosa* and the exotic nipa palm (*Nypa fruticans*) (17; 27). The study area lies within the tropical rainforest zone and has two major seasons: the wet season (April to October) and the dry season (November to March).

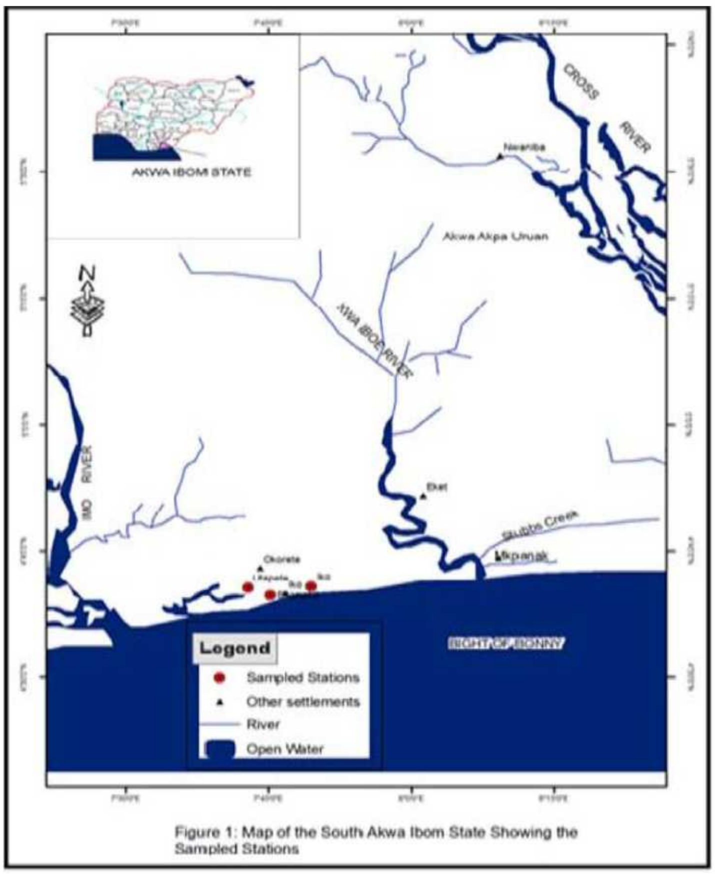

Fig. 1: Map of Iko River Estuary showing the Major Fishing Areas.

2.2 Sample Regime / Collection

Samples of periwinkles (*Tympanotonus fuscatus*) were bought from landings of artisanal fisherfolks in the Iko River estuary on a monthly basis between September, 2022 and August 2023. The samples were then washed thoroughly with the sea water, placed in a labeled cellophane bag, and preserved in ice cooled box. The samples were later transported to the Zoology Department Laboratory of Biological Sciences Akwa Ibom State University and stored in the freezer at - 4°C prior to laboratory analysis.

2.3 Digestion Procedure / Analysis of Heavy Metal

Periwinkles samples were washed and frozen at -5 °C until they were ready for analysis. Later, periwinkles were deshelled and the soft tissues of the periwinkles were air -dried at room temperature for two weeks. The air-dried soft tissues were grounded to powder form, sieved, weighed, and ashed at 77 °C for two hours in a furnace. Ten grams (10 g) of ashed tissues of *T. fuscatus* was digested with 20 ml of concentrated HNO_3 to bring the metal into solution and then transferred to 100 ml plastic can for AAS analysis. Heavy metals were determined using Perkin-Elmer Analysts 800 Atomic Absorption Spectrophotometer (AAS) according to (11).

2.4 Statistical Analysis

MS Excel was used for graphical representation of spatial variations among metal pairs and Statistical Package for Social Sciences (SPSS) version 20 was employed to compute Mean, variance and standard error in the data. Paired sample t-test was used to compare seasons. The probability level was set at p = 0.05. Correlation analysis and Hierarchical cluster analysis was employed using R-software to test for metal association and source of contamination.

3. Results

3.1 Heavy Metals in *Tympanotonus fuscatus*

A summary of the data obtained on seasonal range values, seasonal mean and standard error on heavy metals in *Tympanotonus fuscatus* studied between September, 2022 to August, 2023 is presented in table 1.

3.1.1 Cadmium

Cadmium values obtained for dry and wet seasons ranged between 0.02 – 0.02 mg / kg and 0.02 – 0.07 mg / kg respectively. The mean cadmium values recorded for dry and wet seasons were 0.02 mg / kg ± 0.00 and 0.03 mg / kg ± 0.01 (Table 1). Cadmium concentration were relatively low in the tissue of *T. fuscatus* throughout the dry season (Fig. 2). The results recorded for wet season followed similar trend except for May which had slight variation from the other months (Fig. 3).

3.1.2 Chromium

The range of chromium values obtained for dry and wet season were 0.08 – 0.87 mg / kg and 0.06 – 0.09 mg / kg respectively. The mean chromium values recorded for dry and wet season were 0.22 mg / kg ± 0.13 and 0.08 mg / kg ± 0.00 respectively (Table 1). The concentration of chromium in the tissue of *T. fuscatus* were uniformly low exception of March in the dry season (Fig. 2). Chromium concentration recorded during the wet season were low with the least recorded in the month of October (Fig. 3).

3.1.3 Copper

Seasonal range values for copper recorded in the tissues of *T. fuscatus* for dry and wet season range between 0.13 – 0.14 mg / kg and 0.10 – 1.14 mg / kg respectively. The seasonal mean copper values recorded for dry and wet season were 0.13 mg / kg ± 0.10 and 0.12 mg / kg ± 0.01 respectively (Table 1). No variation was observed in the concentration of copper recorded in the tissue of *T. fuscatus* during the dry season (Fig. 4). Similar trend was reported for wet season exception for May which had a slight variation from the other months (Fig. 5).

3.1.4 Iron

The range concentration of iron values noted for dry and wet season were 1.87 – 2.07 mg / kg and 1.83– 2.99 mg / kg respectively. The mean values recorded for dry and wet season were 1.95 ± 0.03 mg / kg and 1.89± 0.03 mg / kg respectively (Table 2). The concentration of iron in the tissue of *T. fuscatus* was observed to be relatively high when compared to other metals. However, the least concentration was recorded in the month of November, 2022 and the highest value was recorded in the month of April, 2023 (Fig. 2). Similar trend of high iron concentration was also observed in the wet season with the highest value recorded in May, 2023 and the least value recorded in the month of August, 2023 (Fig. 3).

3.1.5 Magnesium

The values obtained for magnesium for dry and wet season was in the range of 0.19– 0.19 mg / kg and 0.17 – 0.20 mg / kg respectively. The mean magnesium values recorded for dry and wet season were 0.20 ± 0.00 mg/kg and 0.19 ± 0.00 mg / kg respectively (Table 1). The concentration of magnesium in the tissue of *T. fuscatus* were uniform with no variation (Fig. 2). The trend was similar for the wet season (Fig. 3).

3.1.6 Nickel

Nickel values for dry and wet season range between 0.03– 0.06 mg / kg and 0.03 – 0.40 mg / kg respectively**.** Mean values for dry and wet season were0.05 ± 0.00 mg/kg and 0.15 ± 0.07 mg / kg respectively (Table 1). Slight variation in nickel concentration was observed during the dry season with the least concentration recorded in the month of December, 2022 (Fig. 2). There was a deviation in the trend during the wet season with high values observed in the month of July, 2023 and the least concentration recorded in the months of September and October, 2022 respectively (Fig. 3).

3.1.7 Lead

The range lead concentration recorded in the tissues of *T. Fuscatus* for dry and wet season range between 0.03 – 0.11 mg / kg and 0.25 – 0.47 mg / kg respectively**.** The mean concentration of lead for dry and wet season were **0.07** ± 0.01 mg/kg and 0.19 ± 0.07 mg / kg respectively (Table 1). The least lead concentration was recorded in the tissue of *T. fuscatus* in the month of November, 2022 while the highest concentration was recorded in the month of April, 2023 (Fig. 2). During the wet season lead concentration showed an interesting pattern with high concentration noted in the month September, 2022 and the least noted in the month of October, 2022 (Fig. 3).

3.1.8 Zinc

Zinc values range from 0.20 – 0.38 mg /kg and 0.22– 0.24 mg / kg for dry and wet season respectively. The mean zinc values recorded for dry and wet season were 0.32 ± 0.02 mg/kg and 0.25 ± 0.01 mg/kg respectively (Table 1). The trend in zinc concentration in the tissue of *T. fuscatus* showed an interesting pattern. The least zinc concentration during the dry season was recorded in the month of April, 2023 while the highest concentration was noted in the month of January, 2023 (Fig. 2). Concentration of zinc in *T. fuscatus* was observed to be higher in the month of October, 2022 with the least value recorded in the month of June, 2023 (Fig. 3).

Table 1: Seasonal range, mean variation, standard error of Heavy Metal measured in Tissue of Tympanotonus fuscatus Caught from Iko River Estuary for wet and dry season (September, 2022 – August, 2023)

Heavy Metals	Units	Range (dry Season)	Range (Wet Season)	Mean ± S.E (Dry Season)	Mean ± S.E (Wet Season)	Maximum limit WHO/FEPA (mg/kg)
Cadmium	mg/kg	0.02–0.02	0.02– 0.07	0.02 ± 0.00	0.03± 0.01	0.5
Chromium	mg/kg	0.08-0.87	0.06-0.09	0.22±0.13	0.08±0.00	0.5
Copper	mg/kg	0.13-0.14	0.10-1.14	0.13±0.10	0.12±0.01	3.0
Iron	mg/kg	1.87-2.07	1.83-1.99	1.95±0.03	1.89±0.03	0.5
Magnesium	mg/kg	0.19-0.19	0.17-0.20	0.20±0.00	0.19±0.00	0.5
Nickel	mg/kg	0.03-0.06	0.03-0.40	0.05±0.00	0.15±0.07	0.5
Lead	mg/kg	0.03-0.11	0.25-0.47	0.07±0.01	0.19±0.07	2.0
Zinc	mg/kg	0.20-0.38	0.22-0.27	0.32±0.02	0.25±0.01	30

Where S.E = Standard Error, WHO = World Health Organization

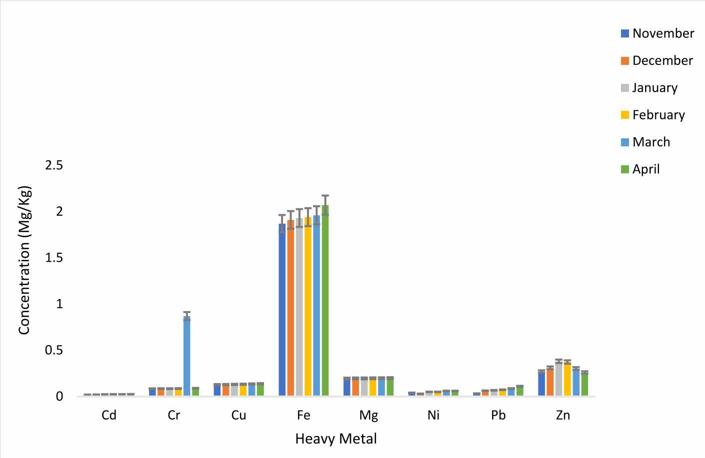

Fig. 2: Mean Heavy Metal Concentration (Mg/Kg) in the Tissue of Tympanotonus fuscatus (Dry Season)

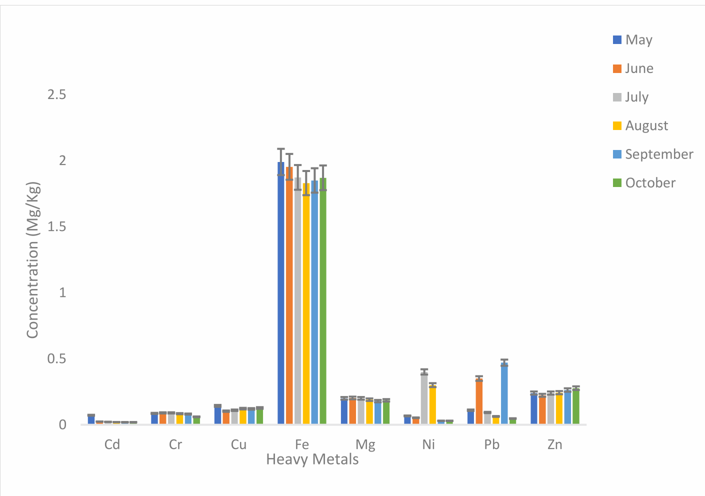

Fig. 3: Mean Heavy Metal Concentration (Mg/Kg) in the Tissue of Tympanotonus fuscatus (Wet Season)

3.2Mean Seasonal variation of Dry and Wet values of Heavy Metal measured in Tissue of *Tympanotonus fuscatus* Caught from Iko River Estuary (September, 2022 – August, 2023).

Mean dry and wet season value of heavy metal in the tissue of *T. fuscatus* is presented in Table 2. The mean concentration of cadmium, nickel and lead were observed to be higher in the wet season than the dry season but with no significant difference at p = 0.05. Similarly, chromium, copper, iron, magnesium and zinc concentration were relatively higher during the dry season than the wet season but no significant difference was observed at p = 0.05 exception for zinc which showed significant at p = 0.05.

Table 2: Mean Seasonal variation of Dry and Wet values of Heavy Metal measured in Tissue of Tympanotonus fuscatus Caught from Iko River Estuary (September, 2022 – August, 2023).

Heavy Metals	Dry	Wet	t-value
Cd	0.023	0.029	0.7152
Cr	0.216	0.081	1.0297
Cu	0.132	0.120	1.927
Fe	1.946	1.894	1.387
Mg	0.196	0.192	0.956
Ni	0.048	0.146	1.489
Pb	0.072	0.316	1.601
Zn	0.247	0.188	3.0927*

t_{crit} = 2.281

3.3 Correlation and hierarchical cluster dendrogram based on heavy metals in Tissue of *Tympanotonus fuscatus* (dry season)

Dry season correlations between heavy metals in the flesh of *Tympanotonus fuscatus*are presented in Fig. 4. Significant positive correlation was observed between the following metal pairs Nickel – Copper (r = 0.87, p<0.05), Nickel-Cadmium (r =0.90, p<0.05); Iron-Copper (r = 0.95, p<0.01), Iron-Cadmium (r = 0.88, p<0.05), Iron-Lead (r= 0.96, p<0.01), Iron-Magnesium (r = 0.92, p <0.05); Mg-Cu (r = 0.95, p<0.01), Mg-Cd (r = 0.95, p<0.01), Mg-Pb (r = 0.99, p<0.001); Pb-Cu (r = 0.95, p<0.01), Pb-Cd (r = 0.94, p<0.01) and Cd-Cu (r = 0.96, p<0.01). Hierarchical cluster analysis (HCA) was used in the classification of the contaminants based on source and concentration gradient respectively. Figure 5 represents a cluster dendrogram showing four cluster group. Cluster group 1 (Cd, Cu), group 2 (Mg, Pb), group 3 (Fe and Ni) and cluster group 4 (Cr and Zn).

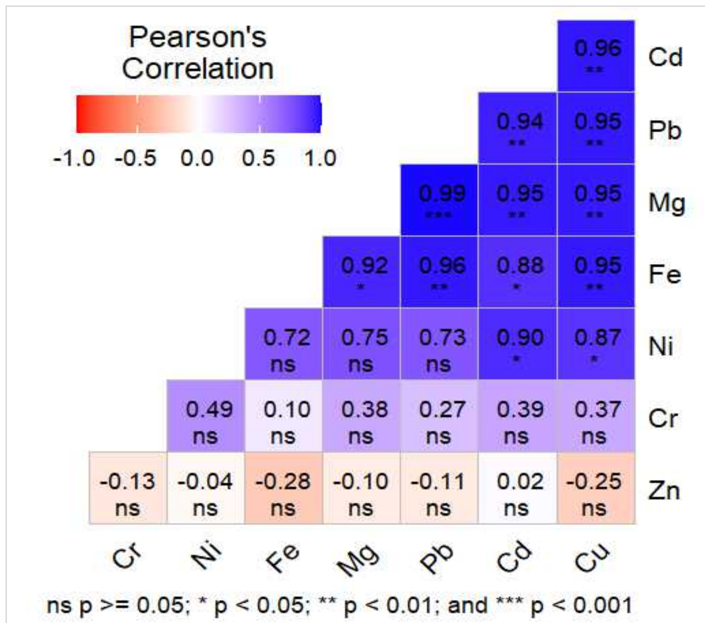

Fig. 4: Dry season Heavy metal correlation in the flesh of Tympanotonus fuscatus

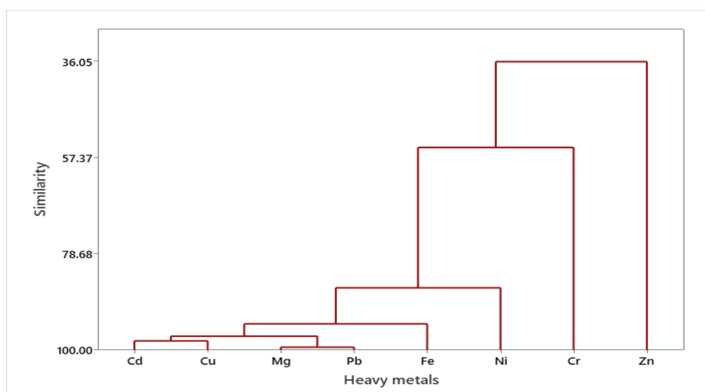

Fig. 5: Dry season Dendrogramfor Heavy Metals in Tympanotonus fuscatus

3.4 Correlation and hierarchical cluster dendrogram based on heavy metals in Tissue of *Tympanotonus fuscatus* (wet season)

The results of heavy metal relationship in tissue of *T. fuscatus* for wet season is presented in Fig. 6. The relationship between metal pairs were not significant exception of a negative correlation observed for zinc. Zinc correlated with magnesium (r = -0.85, p<0.05) and chromium (r = -0.89, p<0.05). Hierarchical cluster analysis for heavy metal in tissue of *T. fuscatus* plotted three (3) cluster group representing two tri-factor group (Cd, Fe and Pb) (Cr, Mg and Ni) and one bi-factor group (Cu and Zn) (Fig 7).

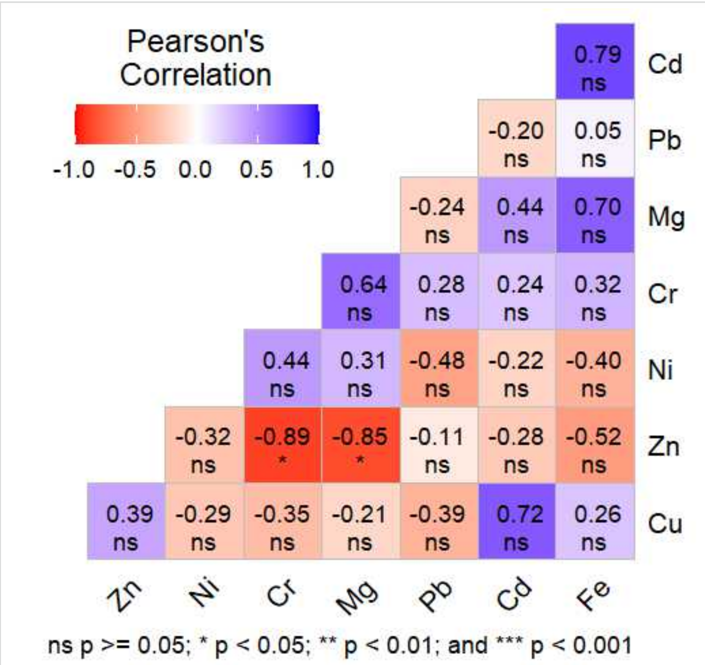

Fig. 6: Wet season Heavy metal correlation in the flesh of Tympanotonus fuscatus

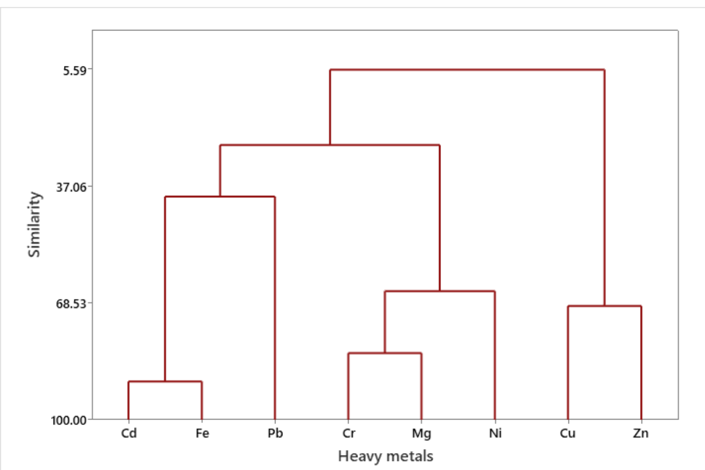

Fig. 7: Wet season Dendrogramfor Heavy Metals in Tympanotonus fuscatus

4. Discussion

4.1 Heavy metal concentration in the tissues of *Tympanotonus fuscatus*

The mean value of heavy metal concentrations in the tissues of the analyzed *Tympanotonus fuscatus* species obtained from Iko River Estuary, showed an interesting pattern. This follows the trend: Fe > Zn > Cr > Mg > Cu > Pb > Ni and Cd for dry season while a different trend was observed for wet season. This follows the trend: Fe > Zn > Mg > Pb > Ni > Cu > Cr and Cd. Fe concentration was observed to be higher in the tissues of the studied specieas compared to other metal concentrations in the study species. Similar trend of high concentration of iron and zinc in tissue *T. fuscatus* have been reported by (21). The high concentration of zinc and iron in tissue of *T. fuscatus* may be attributed to the essential role of these metals as trace metals which are needed in minute concentration for metabolic processes in the organisms. Sources of iron and zinc in aquatic ecosystem are attributed mainly to lithogenic sources (weathering of rocks and soil composition around watershed which are controlled by geological processes) and anthropogenic sources which include smelting of iron ores and indiscriminate discharge of industrial wastes.

However, the concentration of the studied metals was below threshold level when compared to WHO standard for save consumption of *T. fuscatus* from Iko River Estuary. (9) during their studies on Bioaccumulation of Heavy metals and Total Hydrocarbon in tissues of *T. fuscatus* in the intertidal region of Qua Iboe river basin also reported similar results of low heavy metals concentration that were below WHO recommended level. In a related studies of heavy metal concentrations in tissues of benthic aquatic organisms, (16) and (22) reported similar trends of low levels of these metals in the tissue of *Egeriaradiata*caught from Calabar river and Crassostrea gigas from Imo River estuary.

Though, the present study deviates from earlier findings reported by (14) when working on the comparative studies of heavy metal concentrations in tissue and shells of *T. fuscatus* from Okoro Ette River in Eastern Obolo. The authors based on the levels of heavy metals recorded which exceeded the World health organization (WHO) permissible limit for save consumption of aquatic seafood concluded that *T. fuscatus* from Okoro Ette river were not save for human consumption. Similarly, (1) reported high levels of heavy metals in the tissue of *T. fuscatus* from Uta Ewa creek which were above WHO maximum permissible limit. Also, the risk of consumption of *T. fuscatus* from Iko river estuary was reported by (2) based on the elevated concentrations of heavy metal recorded in the tissue of the organism particularly cadmium, copper and iron which were all higher than the WHO / FEPA (World Health Organisation / Federal Environmental Protection Agency) recommended MPL (Maximum Permissible Limit). (23) reported high concentrations of heavy metals in tissue of *T. fuscatus* obtained from qua iboe river estuary that exceeded WHO tolerable limit. Similar, observations were recorded for *Callinectes Amnicola* from Qua Iboe River Estuary by, (20).

The presence of these metals in the tissue of the studied organism is evidence of human perturbations going on in and around the Iko River Estuary. This emphasizes the importance of constant monitoring of rivers and other water bodies receiving effluents in order to forestall cumulative effects of pollution in the river which may lead to sub lethal consequences in the aquatic fauna and clinical poisoning to man via the food chain.

Significant variation in season was not observed throughout the study duration exception of zinc (Zn). This might be attributed to proximity in the concentrations of these metals recorded in both seasons and also, their benthic nature where the burrow in sediments which metal accumulation or bioconcentration are not disturbed by hydrological processes. This finding corroborates with earlier assertion reported by (1) who also reported absence of significant difference in all the metals studied when reporting on heavy metals concentration in tissue of *T. fuscatus* from Uta Ewa creek.

The use of correlation analyses in establishing relationships within and between variables, locations and organisms is well established in literature (13). Positive correlations between metals pairs denotes that an increase in one of these parameters leads to a corresponding increase in the other. These interrelationship patterns may arise from high inflow of particulate matter from run-offs, coastal farmlands and release of untreated sewage into the water leading to an increase in organic materials in the water column. This belief stems from the fact of (24).

The agglomeration patterns observed in the cluster dendrogram representing the metal pairs in Tissue of *T. fuscatus* in both rainy and dry season assorts the metals in line with concentration gradient. Similar observations have been observed by earlier researchers (12; 18).

4.2 Conclusion

The concentrations of heavy metals observed in the tissues of *T. fuscatus* during the study were within permissible limit as recommended by WHO/FAO. To address metal contamination in aquatic ecosystems, comprehensive monitoring programs and stringent regulatory frameworks are essential. Regular assessment of water quality, sediment composition, and the health of aquatic organisms can provide valuable data to track and manage metal pollution. Additionally, public awareness and education campaigns can play a pivotal role in promoting responsible waste disposal and encouraging environmentally friendly practices.In conclusion, metal contamination in aquatic ecosystems is a pressing environmental issue with far-reaching consequences. The adverse effects on aquatic organisms, ecosystems, and human health underscore the importance of adopting sustainable practices, implementing effective pollution control measures, and fostering a collective commitment to preserving the delicate balance of our aquatic environments.

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