Minerals and Trace Elements Content of Selected Shellfish from Opuro-ama Waterfront: An Impacted Tidal Creek in Rivers State, Nigeria

Davies I. Chris,[1*] Nkeeh, D. Koote,[1] and Efekemo Oghenetekevwe.[2]
[1]Department of Fisheries, Faculty of Agriculture, University of Port Harcourt, P.M.B. 5323, Port Harcourt, Nigeria.
[2]Department of Chemical Sciences, Biochemistry Programme, Faculty of Science, Edwin Clark University, Kiagbodo, Delta State, Nigeria.

D.O.I: 10.56201/ijaes.v8.no3.2022.pg45.60

Abstract
In this study, the content of essential minerals, copper (Cu), iron (Fe), manganese (Mn), calcium (Ca), and sodium (Na) in the edible parts of Tympanotonus fuscatus, Thais coronata, Crassostrea gasar, Cardisoma guanhumi and Callinectes amnicola from Opuro-ama creeks, River's state were analyzed using Atomic Absorption Spectrophotometer and descriptive statistical analyses of variance were done using SPSS and significant means were separated using the Duncan multiple range test at 0.05. High Cu content was found in the T. coronata (9.66mg/g) while the lowest was observed in C. amnicola (0.54mg/g). Fe was higher in C. gasar (37.8mg/g) and the lowest in T. fuscatus (6.78mg/g). The concentration of Manganese was highest in C. guanhumi (144.8mg/g) and least T. fuscatus in (15.9mg/g). C. guanhumi recorded the highest (225.1mg/g) Ca content while the least was observed in T. fuscatus (55.8mg/g). T. coronata recorded the highest (2.11mg/g) Na content while the least was found in T. fuscatus (0.22mg/g). Ca was the highest mineral observed in all five shellfish, and the least was Sodium (Ca >Mn.>Fe>Cu>Na). The Physico-chemical parameters such as Temperature (°C), pH, Salinity (ppt), DO (Mgl^{-1}), BOD (Mgl^{-1}) and Conductivity (µS/ cm) observed during the study were all within the acceptable limits of the World Health Organization (WHO), Department of Petroleum Resources (DPR) and Federal Environmental Protection Agency (FEPA). The five shellfish species from the Opuro-ama creeks were shown to be good sources of nutrients at various levels, therefore might be a useful alternative for other materials for animal feed formulation.

Keywords: *Physicochemical, mineral elements, Shellfish, and Creek.*

1. INTRODUCTION

Marine foods are very rich in minerals such as copper (Cu), iron (Fe), manganese (Mn), calcium (Ca), and sodium (Na) [1]. Minerals are minute nutrients that are essential for the biochemical, and physiological interactions in the man's diet [2]. They also ensure adequate immune system and cognitive development, a low level of minerals can cause some health problems such as weak bones, fatigue, or a decreased immune system [2]. Shellfishes comprise invertebrate animals such as rock snails, oysters, crabs, and periwinkle which possess an exoskeleton that may be in a single or double form over the body [3]. There has been a lot of research on the mineral content in several types of aquatic food [4]. Shellfish have been identified as a significant source of minerals and micronutrients in riverine communities, and are abundant in Nigeria's brackish and fresh rivers [5].

Almost all the elements that occur in seawater are found to some extent in shellfishes [2]. Fish's mineral content is inescapable in the diet because it is a source of a variety of minerals that are beneficial to one's health [6]. Minerals are vital in human nutrition because they are found in bones, soft tissues, co-factors, and co-activators of many enzymes. The main activities of important minerals are skeletal structure, colloidal system maintenance, and acid-base balance regulation. Minerals are also found in hormones, enzymes, and enzyme activators, among other things [7].

Shellfishes have been reported as natural sources of nutrients for humans and their consumption increased rapidly over time [8]. Shellfish including oyster (*Crassostrea gasar*), rock-snail (*Thais coronata*), periwinkle (*Tympanotonus fuscatus*), land-crab (*Cardisoma guanhumi*), and lagoon-crab (*Callinectes amnicola*), are also found in Okpoka Creek [9].

There are a variety of shellfish species that live in the Niger Delta as a result of the extensive coastal areas, including creeks, marshes, rivers, streams, ridges of sand beaches, mangroves, and swamps [10]. Several invertebrate species, including periwinkles, rock snails, crabs, and oysters, are considered valuable shellfishery products in West Africa [11] and may play an extremely important role in the Nigerian economy. Consequently, this study is necessary to determine nutritive value by analysing minerals in the marine crabs (*C. amnicola*), periwinkles (*T. fuscatus*), rock snails (*T. coronata*), land crabs (*C. guanhumi*), and mangrove oysters (*C. gasar*) from Opro-ama creek [9]. These species of shellfish were chosen because they were observed to constitute some of the most commonly occurring species in this creek and are often caught as food fish by artisanal fishers in the area. Therefore, studies on these species are considered justified as it is a good food fish utilized to form the creek. The objective was to study and report the mineral contents of these selected shellfish and the physicochemical parameters of the water along the polluted axis of Opuro-ama creek.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out at three (3) different stations {Abala-ama (Station 1), Opuro-ama (Station 2), and Sa-ama (Station 3)} across the Opuro-ama creek which is located in Asari-Toru Local Government Area of Rivers State (Figure 1). The Creek is a tributary of the Sombreiro Estuary, one of the 21 estuaries in the Niger Delta geomorphic unit of Nigeria's extensive (approximately 853 km) coastline[12]. Located southeast of the Niger Delta between longitude N04^0 48' 14.0" and latitude E006^0 50' 16, the Opuro-ama Creek system consists of the main channel and associated feeder creeks linking Abala-ama, Sa-ama, Te-ama community, and other riparian communities. The mangrove vegetation of the area comprises *Rhizophora racemosa, R. mangle, and R. harrisonii* (red mangrove). Other mangrove species in the area are *Avicennia germinans* (white mangrove), *Laguncularia racemosa* (black mangrove), and *Conocarpus erectus (*buttonwood*)*. There is also the presence of mangrove associates such as *Acrostichum aureum* (mangrove fern) and *Paspalum vaginatum* (mangrove sedge). In terms of relative species abundance, the Opuro-ama mangrove is typical of the broader Niger Delta mangrove composition, characterized by the dominance of *R. racemosa*. Sediments of the studied sites were uniformly consolidated, spongy and highly fibrous "chicoco" peaty mud characteristic of many mangrove swamps of the Niger Delta [13,14].

Compared with most mangrove littoral residential areas, in terms of mangrove woodcutting for domestic use, the Opuro-ama mangroves are among the few intact mangrove belts in the eastern Niger Delta; experience less harvesting pressure.

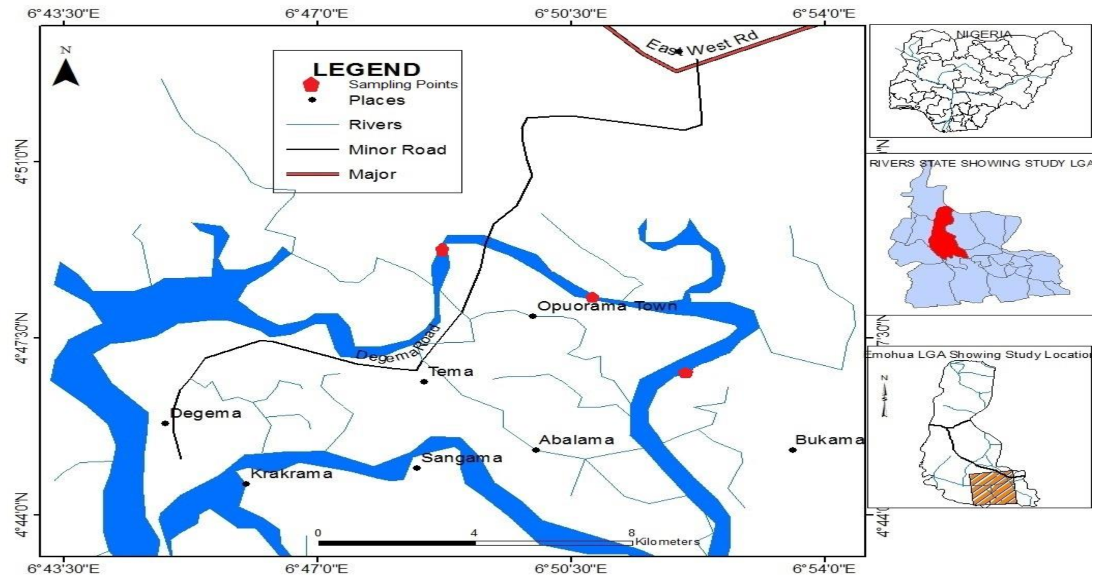

Figure 1: Showing the area of the creek studied.

2.2 Collection of the Samples

A total of twenty representative samples per station at each sampling campaign were obtained within the sampling period (January to June 2021) to provide for statistical variation. The waterways provided healthy species. Periwinkle (*Tympanotonus fuscatus*) and Rock Snail (*Thais coronata*) were hand-picked from the mudflat, while Mangrove oyster (*Crassostrea gasar*) was gathered from the mangrove tree's prop root at low tide. A dragnet was used to catch Swimming Crabs (*Callinectes amnicola*), while a trap was used to get Land Crabs (*Cardisoma guanhumi*). Before being transported to the laboratory for analysis, the collected specimens were kept cold in an ice chest.

2.3 Physicochemical Parameters

The pH, temperature, conductivity, and salinity were measured in situ with a hand-held multi-meter (The EZODO Multi-meter model CTS-406 China). Dissolved Oxygen was measured with a Dissolved Oxygen meter (Milwaukee handheld meter - Model MW 600 China). The probe of the meter was inserted 10-15 cm below the interstitial water and the meter was switched on and allowed to stabilize for 10 minutes. The readings were then taken when the reading became stable. Biochemical oxygen demand was analysed using the 5-day BOD test[15]. The 5ml sample was diluted to 100ml with distilled water. This was poured into two 50ml capacity DO bottles and capped. One of the two test samples was used to determine the initial DO using the Milwaukee DO meter. Another test sample was incubated for 5 days at a temperature of 20^0C before it was analyzed for DO by the above method.

BOD (mg/l) = Initial DO – Final DO

All measurements were done in triplicates.

2.4 Mineral Analysis

The Atomic Absorption Spectrophotometric method16 was used to determine the trace elements and mineral concentrations in the samples. A sample of 1.0g of dried was weighed out and placed in an earlier weighted and dried porcelain crucible, which was dried in a 105^{o}C oven for 30 minutes. The crucible and its contents were then heated for 3 hours at

550°C in a muffle furnace to form ash. Afterward, 5ml of concentrated HCl was then added to the ash and mixed using a glass rod, followed by 20ml of distilled water, and the crucible's contents were heated on a plate until they were half their original volume. The solution is allowed to cool and filter into a 50ml volume flask. For analysis, the mineral assay was taken to the Atomic Absorption Spectrophotometric. After that, the wavelength of each of the elements was chosen, and the air and gas flow were adjusted as needed. (Mn = 279.5 nm, Cu = 324.7 nm, Fe =248.3 nm, Na =589.9 nm and Ca = 422.7 nm,). All procedures were as described by Davies and Jamabo (2016)

The percentage (%) of the element was calculated using the following equation;

$$= \frac{C\ (ppm) \times \text{solution Vol.(ml)}}{10^3 \times \text{sample Wt (g)}}$$

Where C represents the concentration of elements in the digest as indicated.

These results were given in milligrams per 100 grams of the specimen. All measurements were made in triplicate, and the process was repeated for each species.

2.5 Statistical Analysis

Statistically, data were analyzed using a one-way analysis of variance (ANOVA) and Duncan's multiple range tests to compare the mean values of the samples and to avoid errors inherent in performing multiple *t*-tests. Results were tested for statistically significant differences at the 0.05 level.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Physiochemistry of the Interstitial Water

The physicochemical parameters of the interstitial water from the Opuro-ama Creek are described in Table 1.

Table 1: Mean values of the physicochemical parameters of interstitial water

Parameters	Opuro-ama		WHO Limit	DPR Limit	FEPA Limit
	Range	Mean± SE			
Temperature (°C)	26.0 -26.8	26.4±0.23	27.8-30°C	30	27.8/30
Ph	6.8 – 6.99	6.89±0.54	6.5-8.5	6-9	6.5-8.5
Salinity (ppt)	11.2 – 12.0	11.6 ±0.22	-	600	-
DO (Mgl^{-1})	4.6 -4.10	4.10±0.29	3-5mg/L	20	-
BOD (Mgl^{-1})	1.9 -2.4	2.16±0.15	10mg/l	125.0mg/l	50 mg/L
Conductivity (µS/ cm)	12.5±12.6	12.56±0.03	1000µS/cm	-	<2000 200-1000

**Note:* *DO: Dissolved oxygen, BOD: Biological oxygen demand, and pH: Negative log of hydrogen ion concentration. WHO: World Health Organisation, DPR: Department of petroleum hydrocarbon, FEPA: Federal Environment Protection Agency.*

The temperature values ranged from 26.0°C to 26.8°C with a mean value of 26.4±0.23 in Opuro-ama Creek. The pH values of the interstitial water varied between 6.2 - 6.8 and 6.8-6.99 with a mean value of 6.89±0.54 while the salinity values range from 11.2‰ - 12.0‰) with a mean value of 11.6 ±0.22. Dissolved oxygen values vary between 4.1- 4.6mg/l with a mean value of 4.10±0.29. The Biological Oxygen Demand varies between 1.9 - 2.4 mg/l with a mean value of 2.16±0.15. Conductivity values varied between 12.5-12.6µS/cm^{-1} with a mean value of 12.56±0.03. There was a statistical difference in the parameters across the stations.

3.1.2 Mineral content

The concentrations of essential metals in shellfish edible parts of *T. coronata, C. gasar, T. fuscatus, C. amnicola, and C. guanhumi* from Opuro-ama Creeks measured in mg/100g of the fish sampled are shown in Table 2 and Figure 3 to 7.

Table 2: The mean value of the mineral trace and element concentrations in the shellfishes

Minerals(mg/g)	*T. fuscatus*	*T. coronata*	*C. gasar*	*C. guanhumi*	*C. amnicola*
Copper	3.38 ± 0.05^{b}	9.66 ± 0.02^{a}	0.56 ± 0.01^{d}	1.97 ± 0.01^{c}	0.54 ± 0.02^{d}
Iron	6.78 ± 0.06^{e}	14.6 ± 0.05^{c}	37.8 ± 0.01^{a}	24.6 ± 0.31^{b}	9.72 ± 0.03^{d}
Manganese	15.9 ± 0.03^{e}	19.2 ± 0.01^{d}	98.4 ± 0.02^{c}	144.8 ± 0.05^{a}	142.7 ± 0.63^{b}
Calcium	55.8 ± 0.19^{e}	139.2 ± 0.58^{c}	69.6 ± 0.04^{d}	225.1 ± 17.8^{a}	211.3 ± 0.68^{b}
Sodium	0.22 ± 0.01^{e}	2.11 ± 0.01^{a}	0.74 ± 0.03^{c}	0.47 ± 0.01^{d}	1.03 ± 0.02^{b}

* *Rows with a common letter are not significantly different (P>0.05)*

* *Rows with the different letters are significantly different (P<0.05)*

3.1.3 Copper content

The copper content of the edible parts of the shellfish found in Opuro-ama Creek, T. coronate recorded the highest copper content (9.66±0.02 followed by T. fuscatus (3.38±0.05mg/g while *C. amnicola* recorded the lowest copper content (0.54 ± 0.02mg). Different shellfishes from creeks differed significantly ($p < 0.05$) in copper content

3.1.4 Iron content

The amount of iron observed in the shellfish from Opuro-ama Creek is presented in Table 1. *C. gasar* recorded the highest iron content (37.8±0.01mg/g) followed by *C. guanhumi* (24.6±0.31mg/g) while *T. fuscatus*(6.78±0.06mg/g) recorded the least iron content. There was a significant difference ($p<0.05$) between all the five shellfish sampled in the creek.

3.1.5 Manganese content

The highest value of Manganese was recorded in *C. guanhumi* (144.8±0.05mg/g) followed by *C. amnicola* (142.7±0.63mg/g) and the least was recorded in *T. fuscatus* (15.9±0.03mg/g). There was a significant difference ($p<0.05$) observed in the manganese content for the five shellfish in Opuro-ama Creek.

3.1.6 Calcium content

C. guanhumi produced the highest calcium intensity (225.1±17.8mg/g) followed by *C. amnicola* (211.30.68mg/g); *T. fuscatus* measured the least amount (55.8±0.19mg/g). There was a consistent difference in manganese content across the five shellfish at Opuro-ama ($p< 0.05$).

3.1.7 Sodium content

The sodium content of the species from Opuro-ama Creek recorded a substantial difference ($p < 0.05$). Sodium was highest in *T. coronata* (2.11±0.01mg/g) followed by *C. amnicola* (1.03 ± 0.02mg/g) and the least value was recorded in *T. fuscatus* (0.22±0.01mg/g). There was a notable variation observed ($P < 0.05$) in the sodium level in all the shellfish obtained.

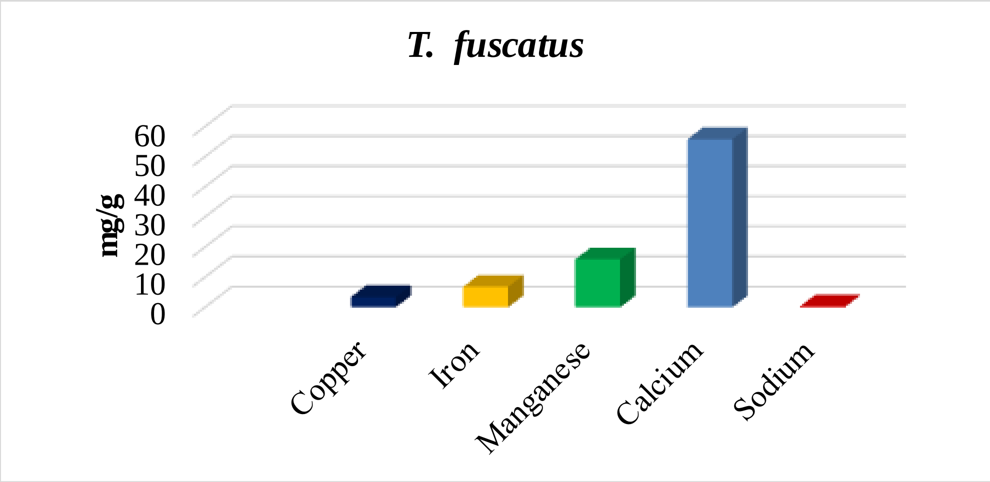

Figure 2: Mineral element concentrations (mg/g) in the flesh of *T. fuscatus*

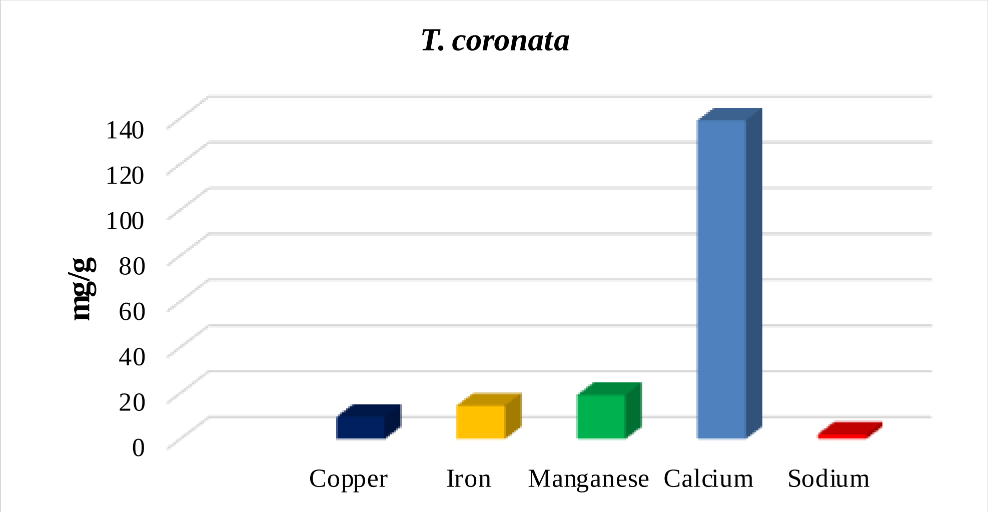

Figure 3: Mineral element concentrations (mg/g) in the flesh of *T. coronate*

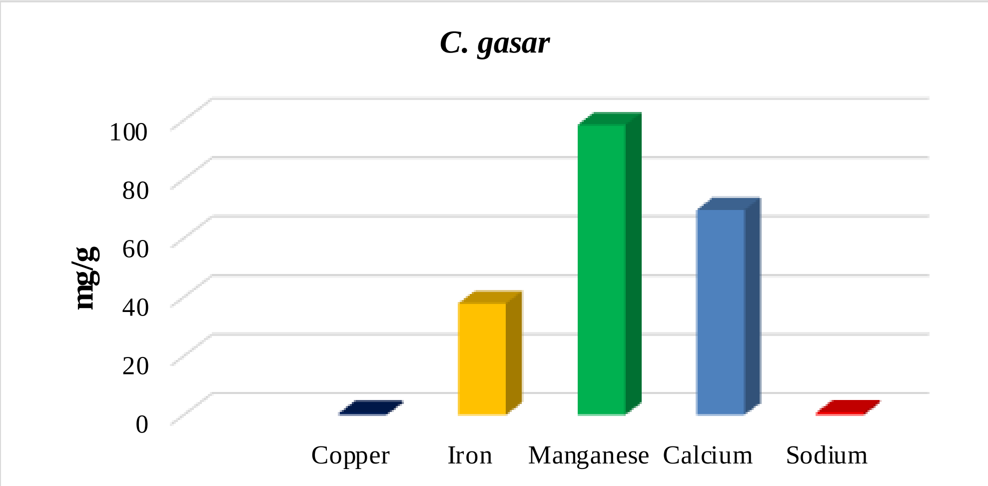

Figure 4: Mineral element concentrations (mg/g) in the flesh of *C.gasar*

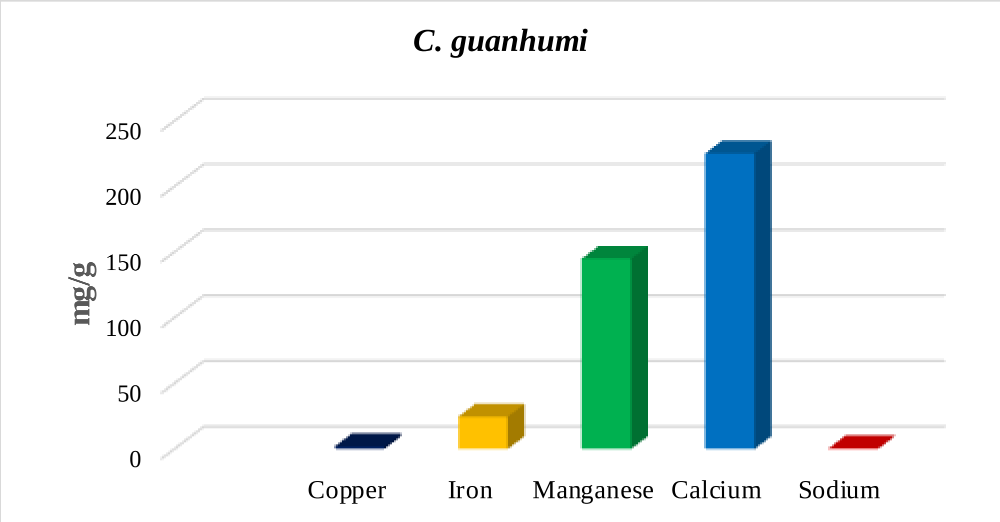

Figure 5: Mineral element concentrations (mg/g) in the flesh of *C. guanhumi*

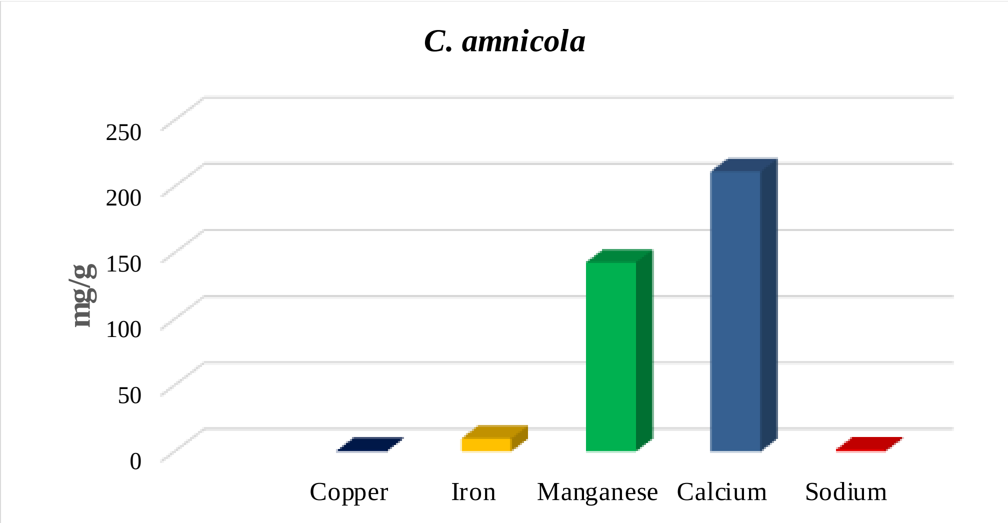

Figure 6: Mineral element concentrations (mg/g) in the flesh of *C. amnicola*

3.2 DISCUSSION

3.2.1 Physicochemical Parameters of the Interstitial

The physicochemical parameters in any aquatic environment create a balance in nutrition and also direct the biotic interactions between organisms and their environment [16]. Because temperature influences physical, chemical, and biological processes within water bodies, the concentration of many variables can change the nature and amount of food eaten by fish, as well as what minerals they absorb directly from the water through their gills and body surfaces [17]. Changes in the temperature of any environment can affect all life processes either positively or negatively because it is an important factor that also affects the solubility of gases and salts in water18. In the present study, it was observed that the interstitial water temperature fluctuates between 26.0°C and 26.8°C. Similar temperatures were also observed by [19] ranging from 25.4 to 27.1°C. The values were within the acceptable limit of [20,21]. A similar observation was also reported by [22]. They attributed the variation to the combination of various environmental factors that govern many physiological and biological processes of the different water bodies. However, similar results were also reported by [23] in Woji creek (25.8 to 30.4°C). Although, [24] reported a high temperature ranging from 28 and 32°C in the New Calabar River.

The pH range of the interstitial water from the creek was between 6.8 and 6.99 and can be classified as mesohaline (6.2-13.1%0). The pH could also be influenced by the acidity of the bottom sediment and biological activities in the sediment [22]. The variation in the high density of leaf-littered around the sediment and the subsequent decay could have contributed to the slightly acidic nature of the interstitial water from the creek [25]. The pH range of the interstitial water also falls within the optimum range of most aquatic organisms which are 6.5-8.5°C, 6-9°C, and 6.5-8.5°C respectively, and will support rich primary productivity, shrimp and fish production as reported by [20, 21, 26].

The salinity gradient of the tidal flats in brackish waters increases downstream due to the inflow of oceanic waters and the decreasing influence of the river and runoff-derived freshwater [27]. The salinity of the interstitial water from the study varied between 11.2 – 12.0 and was within the permissible limit recommended by21. The salinity was lower than 16.93 and 20.28 as reported [28] in the interstitial water in Bodo Creek during the rainy and dried seasons. [29] reported higher values of 138.1 and 175.0 from oilfield wastewater from Kolo creek flow station and EPU 05 located in Bayelsa State, Nigeria. The low salinity values recorded in this study could be attributable to localized seepage since the salinity of interstitial water represents a balance between seawater that periodically submerges the intertidal area and freshwater seeping out from the land [28]. According to [30], dilution by rains and concentration by evaporation account for the wide salinity variations on intertidal flats. However, the variation in salinity could also be due to the variation caused by a sudden rise in salinity at different times and seasons according to the activities around the sampled stations such as the pollution caused by human activities [31]. This is not uncommon in estuaries which are known for their unstable environmental conditions [32].

Oxygen plays a vital role in any living ecosystem and the amount of dissolved oxygen in water depends on the temperature of the environment and the surface area exposed. In the present study, the dissolved oxygen values in the interstitial water vary between 4.1- 4.6mg/l. these values were above the permissible limit by [20] which is 3-5mg/L, although the values were below the recommended value (20mg/L) by [21]. The variation could be attributed to the use of oxygen by micro-organisms for the decomposition of macrophytes in the sediment [33]. The decaying of aquatic macrophytes also leads to a decrease or increase in the dissolved oxygen level in the interstitial water [34]. This agrees with [35] who reported that the level of oxygen concentrations can also be the result of the presence of decaying organic matter, resulting in the production of toxic gases such as hydrogen sulphide and methane in the water. This was also in agreement with the temporal variations of physicochemical parameters of interstitial water in the Andoni flats as reported by [36].

It is vital for the productivity of aquatic organisms, their survival, and their support that BOD quality is maintained in aquatic environments [22]. The BOD value ranged between 4.6 -4.10 and was within the acceptable limit (10mg/l, 125.0mg/l, and 50 mg/L) of [20, 21, 26] respectively. The BOD values were lower than what [37] reported for the Imo River Estuary of the Niger Delta mangrove ecosystem. The variation might be attributed to the level of pollution by anthropogenic activities along the Opro-ama creek. This agrees with [38] who reported that Oxygen solubility is considerably lower to consumptive processes when the intertidal area becomes exposed to aerial weather; the condition of sampling. The variation may also be associated with the relatively stable level of pollution he observed in Imo River Estuary [39] and the physiological processes of aquatic life [37].

The conductivity obtained conductivity values varied between 12.5 to 12.6µS/cm-1 with a mean value of 12.56µS/cm-1. The values were lower than what [40] reported in New Calabar River, Niger Delta which ranges from 16 to 130.7µS/cm-1. The value was also lower than the value (11059.49µS/cm) reported by [41] in Tin Can Island Creek, Lagos. The value obtained from this study was within the permissible limit of WHO (1000µS/cm) and FEPA (200-10006µS/cm-1). This might be attributed to the fact that the conductivity is directly proportional to the number of salts dissolved in the water and most water bodies show significantly high conductivity values when more dissolved salts are present in them [40]. This also agrees with what [42] Smith (1996) reported on the mangrove sediment in the Clarence River; whereas [43] reported extremely low values of 3.8-10.0 µScm-1 in the Shiroro Reservoir (freshwater), Nigeria. The conductivity of the interstitial water from both Creeks observed in this study conforms with [44] who reported that the conductivity of most water bodies ranges from 10-1000µscm-1 but may exceed 1000 µscm-1, especially in polluted waters, or those receiving large quantities of land run-off.

3.2.2 Mineral content

Marine foods are rich sources of minerals with a total content of minerals in the raw flesh of marine fish and invertebrates ranging from 0.6-1.5% wet weight [2]. Mineral components such as copper, iron, manganese, calcium, and sodium are important for human nutrition9. Crustaceans are also good sources of various minerals and high-quality protein. Crabmeat is an excellent source of minerals, particularly calcium, iron, zinc, potassium, and phosphorus [45]. Living organisms require trace amounts of some heavy metals including iron, cobalt, copper, manganese, molybdenum, strontium, vanadium, and zinc. Excessive levels of these metals, however, can be detrimental to living organisms [22]. The trace element and mineral element concentrations of the fleshy parts of *T. coronata, C. guanhumi T. fuscatus, C. gasar, and C. amnicola* from Opuro-ama creeks in mg per 100g of sample are presented in Table 2. The analysis of minerals composition comprises copper, iron, manganese, calcium, and sodium in all the species. The five species of shellfishes evaluated in this study are important commercial species that are consumed by inhabitants of the River State and other coastal areas in the Niger Delta and other parts of the world because of their nutritional benefits.

Results obtained for the mineral composition of the five economical shellfishes *C. Amnicola, T. coronata, C. guanhumi, T. fuscatus, and C. gasar* in this study showed that these shellfishes were rich in nutritional qualities which varied significantly ($P<0.05$) among each other. From the study, *T. coronate* recorded the highest copper content (9.66mg/g) followed by *T. fuscatus* (3.38mg/g), and the least concentration was observed in *C. amnicola* (0.54mg/g). In this study, the following trends were observed: *T. coronate*> *T. fuscatus*> *C. guanhumi*> *C. gasar*> *C. amnicola*. This copper content varies significantly from these species of shellfish reported by [9] from Okpoka. the dietary differences could be explained by the environments, habitats, and ecological interactions they live in, along with their size.

Calcium is important in blood clotting, muscle contraction, and certain enzymes in metabolic processes [46]. It is an important mineral that helps in bone and shell formation [9]. It also plays a major role in blood clotting, muscle contraction, and metabolic processes. The calcium content in the flesh of all the five shellfish species had the following trend; *C. guanhumi*> *C. amnicola.*> *T. coronate*>*C. gasar*> *T. fuscatus*. Calcium was highest in *C. guanhumi* (225.1mg/g) the least concentration was (55.8mg/g) in *T. fuscatus*. A similar concentration of calcium was reported in the edible part of *C. guanhumi* by [9]. This also coincided with the study of *C armatum* cited by [47]. Shellfish from the aquatic environment ingest rich mineral sources, thus producing high concentrations that could be explained by the feeding habit of the shellfish. This agrees with [48] who reported that shellfish meat is a good source of minerals particularly calcium and potassium. Overall calcium content in these species indicated that the shellfish is a good source of calcium minerals and can serve as a source of calcium supplement in the human diet [49]. The high calcium content observed in these species is an indication of calcium carbonate level in the water and thus is a paramount nutrient needed by these organisms for their shell growth and development [9].

Sodium is a very important mineral since it helps in regulating the pH, nerve impulse transmission, water balance, osmotic pressure, and transportation of glucose/amino acid in a living system [50]. The sodium content of the edible parts of the five species from Opuro-ama Creek varied significantly across the different shellfish species. Sodium was the highest concentration observed in *T. coronata* (2.11mg/g) and the least was recorded in *T. fuscatus* (0.22mg/g). The observed for sodium in this study was as follows: *T. coronate> C. amnicola> C. gasar> C. guanhumi> T. fuscatus* This trend is similar to the trend reported by [9] for the same species sampled from Okpoka Creeks in Rivers State, Nigeria. The value of sodium in *C. amnicola* agrees with [51]. There were reported studies of this same species, but at a lower level by [52] for freshwater crab *Spiralothelphusa hydrodroma*. The variation in sodium mineral content could be a result of its concentration in the water and the physiological need of the organism [50]. [53] stated that the differences in sodium concentration among shellfish could be the type of food they eat and the different types of minerals they absorb directly from their aquatic environment through their gills and body surfaces. According to [54], the concentration of minerals in tissue and other parts of shellfishes can be influenced by different factors such as season, food source, environmental parameters (salinity, temperature water chemistry, and contaminants), and biological attributes (species, size, age, sexual maturity, and sex). The sodium concentration obtained in this study is similar to the finding of [55,1] on the same species from the Cross River.

Iron has been reported to have several vital functions in the body [56]. It helps in careering oxygen to the tissues from the lungs by red blood cell haemoglobin and also serves as a transport medium for electrons within cells and as an integrated part of important enzyme systems in various tissues [57].

The iron contents of the shellfish from Opuro-ama were investigated, and it was discovered that each species carried iron at various levels. *C. gasar,* on the other hand, had the highest value (37.8mg/g), followed by *C. guanhumi* (24.6mg/g), and *T. fuscatus* (6.78mg/g). This is in agreement with the findings of [58], who found that rock mineral quality affects the amount of iron in certain soils where snails are raised. [56] reported that the iron concentrations of different fish species varied between 11.20 to 154.19 mg/kg. The Fe concentrations of crustaceans varied from 9.32 to 156.30 mg/kg; spiny lobster had the lowest Fe concentration while shamefaced crab had the highest. [59] reported the presence of pure Fe (4.3 mg/kg) in fish hake. [59] reported that blue whiting contained 4 mg/kg Fe. The concentration of iron was found to be 13.9 mg/kg in white shrimp [60], 113-68 mg/kg in blue crab and swim crab54, 108-850 mg/kg in prawn species61, and 35-40 mg/kg in crab [62]. Sufficient iron in the diet is very necessary for decreasing cases of anaemia, which is known as a major health challenge, especially for pregnant women and sick people. The significant iron level found in *C. gasar* supports the findings of [63], who claimed that the local oyster may be a year-round supply of iron.

In Opuro-ama Creek, the highest manganese levels were detected in *C. guanhumi*, followed by *C. gasar*. From Okpoka Creek. The manganese content of *C. guanhumi* was higher than in *C. armatum* [47,64,65]. Different dietary patterns and other environmental factors could account for the difference in manganese concentrations. Among other functions, manganese is a key trace element for regular body function and is required for a chemical reaction to produce collagen, a structural component of the skin [64]. As well as being an essential trace element, manganese also functions as a co-factor for an enzyme (prolidase) necessary for collagen to function as a structural component of the skin [65]. In addition, manganese is required for bone growth. It also functions as an enzyme system activator, but the link to deficient symptoms in crustaceans isn't clear [66]. All five shellfish species exhibited the same manganese concentration in their flesh: *C. guanhumi*> *C. amnicola*> *C. gasar*> T. coronate > *T. fuscatus*. *T. fuscatus* (15.9mg/g) had the highest manganese value (144.8mg/g), whereas *C. guanhumi* (144.8mg/g) had the lowest. The manganese concentration of the five shellfish in Opuro-ama Creek was found to differ significantly ($p<0.05$). The discrepancy in manganese concentration could be attributable to their different dietary patterns as well as other environmental factors [9]. This agrees with [66] who also reported a high concentration of manganese with a significant number of 87% in all samples from Mediterranean Blue Mussel (*Mytilus galloprovincialis*) from the Bay of Mali Ston Adriatic Sea. Although, the concentration of manganese in *C. guanhumi* was higher than that reported by [47 and 65] reported on *Cardisoma armatum*. This agrees with the assertion by [65] who stated that fish and shellfish can absorb minerals directly from the aquatic environment through gills and body surfaces.

4.0 CONCLUSION AND RECOMMENDATION

In conclusion, the present study revealed that the mineral content of the shellfish species (*T. coronate, C. gasar, C. guanhumi, T. fuscous, C. mnicola, and C. gasar*) from the Opuro-ama tidal flat sampled along the Opuro-ama creek was within the acceptable standard of FAO and the water physicochemical parameters of the creek were also within the World Health Organisation, (WHO), Department of petroleum hydrocarbon (DPR) and the Federal Environment Protection Agency (FEPA) acceptable standard. The five shellfish species described can provide good protein sources at a variety of levels, making them desirable as meat, finfish, or animal feed alternatives because of their high mineral content, which includes calcium, manganese, iron, copper, and sodium. Shellfish provide an excellent source of various minerals that are relatively inexpensive in comparison to other high-protein foods such as fatty foods, poultry, and dairy products. The ingestion of these shellfish and other marine goods has always been an important part of the coastal population's income and diet. These shellfish can be used to make meat, finfish, and animal feed replacements.

Considering the enormous nutritional, commercial, and industrial importance of these shellfishes, it is recommended that an awareness campaign should be carried out in the nearby communities around these creeks to discourage the load of anthropogenic activities that may ease the release of effluents and other pollutants into the aquatic environment which may harm shellfish culture and production of commercial levels nutrients available for the Nigerian population.

COMPETING INTERESTS

The Authors declare no conflicts of interest exist and have no relevant financial or non-financial interests to disclose.

REFERENCES

1. Ivon, E. A., and Eyo, V. O. (2018). Proximate composition and mineral contents of the edible part of four species of shellfish from the Calabar River, Nigeria. Annual Research & Review in Biology, 1-10.
2. Soundarapandian, P., Varadharajan, D., and Sivasubramanian, C. (2013). Mineral composition of edible crab, Charybdis natator Herbst (Crustacea: Decapoda). J. Bioanal. Biomed, 5(4), 99-101.
3. Venugopal, V., and Gopakumar, K. (2017). Shellfish: nutritive value, health benefits, and consumer safety. Comprehensive Reviews in Food Science and Food Safety, 16(6), 1219-1242.
4. Moss, M. L., and Erlandson, J. M. (2010). Diversity in North Pacific shellfish assemblages: the barnacles of Kit'n'Kaboodle Cave, Alaska. Journal of Archaeological Science, 37(12), 3359-3369.
5. Oladunjoye, R. Y., Fafioye, O. O., Bankole, S. T., Adedeji, A. H., and Edoh, A. S. (2021). Heavy metals in shellfish of Ojo River, Lagos State, Nigeria. Agro-Science, 20(3), 99-103.
6. Eyo, A. A. (2001). Fish Processing Technology in the Tropics, National Instit. Fresh Water Fish. Res. (FIFR) New Bussa Nigeria, 66-130.
7. Belitz, H. D., and Grosch, W. (2001). Schieberle, P. Lehrbuch der Lebensmittelchemie, ISBN 3-540-41096-1 5. Aufl. Springer Verlag, Berlin Heidelberg New York.
8. Marcovecchio, J. E., De Marco, S. G., Buzzi, N. S., Botté, S. E., Labudia, A. C., La Colla, N., & Severini, M. D. F. (2015). Fish and seafood. *Handbook of mineral elements in food*, 621-643.
9. Davies I. C. and Jamabo N. A. (2016). Determination of Mineral Contents of Edible Parts of Shellfishes from Okpoka Creeks in Rivers State, Nigeria. International Journal of Fisheries and Aquaculture Research.Vol.2 (2):10-18.
10. Jamabo, N.A. (2008). Ecology of *Tympanotonus fuscatus* (Linnaeus, 1758) in the mangrove swamps of the Upper Bonny River, Niger Delta, Nigeria. Ph.D. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, pp: 231.
11. Nalan, G., Dlua, K. and Yerlikayaa, P., (2003). Determination of proximate composition and mineral contents of blue crab (Callinectes sapidus) and swimming crab (*Portunus pelagicus*) Caught from the Gulf of Autlya, Food Chem., 80:495-498.
12. Zabbey, N., Ekpenyong, I.G., Nwipie, G.N., Davies, I.C. and Sam, K. (2021): Effects of fragmented mangroves on macrozoobenthos: a case study of mangrove clearance for powerline right-of-way at Oproama Creek, Niger Delta, Nigeria, African Journal of Aquatic Science, 1-11.
13. NDES (1997). Niger Delta Environmental Survey: Final Report Phase. 1. Environmental and Socio-Economic Characteristics. Environmental Resource Managers Limited.
14. Cheese, W. (2011). Comparative Effects of Local Coagulants on the Nutritive Value, in vitro Multienzyme Protein Digestibility and Sensory Properties of. International journal of dairy science, 6(1), 58-65.
15. American Public Health Association (APHA). (2005). Standard methods for the examination of water and wastewater, 20th edition (Revised edition), American Public Health Association NY USA, 1076.
16. Sullivan, D. M., & Carpenter, D. E. (1993). Methods of analysis for nutrition labelling. AOAC international.
17. Okere, M. C., Davies, I. C., and Onyena, A. P. (2021). Variation of The Physico-Chemical Parameters, Nutrients and Some Selected Heavy Metals Around the Waters of

the Tincan Island in Lagos, Nigeria. British Journal of Environmental Sciences Vol.9, No.4, pp. 1-17.

18. Okonkwo, S. E, Davies I. C, and Okere M.C. (2021): Assessment of Physico-Chemical Characteristics and Phytoplankton of a Polluted Tidal Creek InAjegunle, Lagos. British Journal of Environmental Sciences 9(1): 51-69.
19. Nwokoma, D. B. M., and Dagde, K. K. (2012). Performance evaluation of produced water quality from a nearshore oil treatment facility. Journal of Applied Sciences and Environmental Management, 16(1), 27-33.
20. WHO (World Health Organization) (2006). Revision of the WHO Guidelines for Water Quality Report of the First Review Group Meeting on Inorganics, (Netherlands) World Health Organization Geneva WHO/PEP/91.18.
21. DPR (2002). Environmental Guidelines and Standards for the petroleum Industry in Nigeria (Revised Edition). Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources. Press, Lagos.
22. Davies, I. C., Agarin, O. J., and Onoja C. R. (2021). Study On Heavy Metals Levels and Some Physicochemical Parameters of a Polluted Creek Along the Tin Can Island in Lagos. International Journal of Environment and Pollution Research.Vol.9, No.2 pp.25-39.
23. Hart, A. I., & Zabbey, N. (2005). Physico-chemistry and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria. Environment and Ecology, 23(2), 361-368.
24. Ekeh, I. B., and Sikoki, F. D. (2003). The state and seasonal variability of some physicochemical parameters in the New Calabar River, Nigeria. Supplemental Ad Acta hydrobiologica, 5, 45-60.
25. Okere, M.C., Davies, I.C. and Okonkwo, S.E. (2020). Seasonal Variation of the Hydro-Environmental Factors and Phytoplankton Community around Waters in Tincan Island, Lagos State, Nigeria. Journal of Applied Sciences & Environmental management. 24(10) 1739-1746.
26. FEPA (Federal Environmental Protection Agency) (1991). National Guidelines and Standards for Industrial Effluents and Water Quality Tests FEPA (Nigeria) Official Gazette, Nigeria.
27. Montagna, P., Palmer, T. A., and Pollack, J. B. (2012). Hydrological changes and estuarine dynamics (Vol. 8). Springer Science and Business Media.
28. Zabbey, N. (2012). Spatial and temporal variability in interstitial water quality of soft-bottom flats at Bodo creek, eastern lower Niger Delta, Nigeria. Tropical Freshwater Biology, 21(1), 83.
29. Ntongha, O., and Wemedo, S. A. (2019). Assessment of Physicochemical Qualities of Oilfield Wastewater in Bayelsa State, Nigeria. Advances in Research, 1-6.
30. KNOX, G.A (2001). The ecology of seashores. CRC Press. 557 p. US $90. ISBN 0-8493-0008-8.
31. Gao, Y., Zhou, F., Ciais, P., Miao, C., Yang, T., Jia, Y., ... and Yu, G. (2020). Human activities aggravate nitrogen-deposition pollution in inland water over China. National Science Review, 7(2), 430-440.
32. Cubillos, V. M., Ramírez, E. F., Cruces, E., Montory, J. A., Segura, C. J., and Mardones, D. A. (2018). Temporal changes in environmental conditions of a mid-latitude estuary (southern Chile) and its influences on the cellular response of the euryhaline anemone Arthropleura hermaphroditical. Ecological indicators, 88, 169-180.

33. Zhang, Y. L., Li, H. B., Xu, L., Pan, X., Li, W. B., Liu, J. and Dong, M. (2019). Pond-bottom decomposition of leaf litters canopied by free-floating vegetation. Environmental Science and Pollution Research, 26(8), 8248-8256.
34. Paccagnella, Y. C., Bianchini, I., and da Cunha-Santino, M. B. (2020). Decomposition dynamics of two aquatic macrophytes: response of litter interaction with temperature and dissolved oxygen availability. Brazilian Journal of Botany, 43(4), 1047-1059.
35. Garg, S., Rose, A. L., and Waite, T. D. (2011). Photochemical production of superoxide and hydrogen peroxide from natural organic matter. Geochimica et Cosmochimica Acta, 75(15), 4310-4320.
36. Gijo, A. H., Hart, A. I., and Seiyaboh, E. I. (2016). The Impact of Makeshift Oil Refining Activities on the Physico-Chemical Parameters of the Interstitial Water of the Nun River Estuary, Niger Delta, Nigeria. Biotechnol. Res, 2(4), 193-203.
37. Unimke, A. A., Antai, S. P., and Agbor R. B. (2014). Influence of Seasonal Variation on the Microbiological and Physicochemical Parameters of Imo River Estuary of the Niger Delta Mangrove Ecosystem. American International Journal of Biology, Vol. 2, No. 1, pp. 61-7.
38. Garcia-Ochoa, F., Gomez, E., Santos, V. E., and Merchuk, J. C. (2010). Oxygen uptake rate in microbial processes: an overview. Biochemical engineering journal, 49(3), 289-307.
39. Oyewo, E. O. and Don-Pedro, K. N. (2003). Estimated annual discharge rates of heavy metals from industrial sources around Lagos; a West African Coastal Metropolis. West African Journal of Applied Ecology, 4(1):115-126.
40. Akankali J.A. and Davies I.C. (2018). Assessment of Heavy Metal Pollutants (Zn & Pb) in New Calabar River, Niger Delta, Nigeria. International Journal of Fisheries and Aquatic Studies. 6(2): 436-441.
41. Agarin, O.J., Davies I.C., and Oyema, I.C. (2019). Evaluation of some physicochemical parameters of the Tin Can Island Creek, Lagos, Nigeria, Nigerian Journal of Fisheries, 16(2):1783-1793.
42. Smith, P. T. (1996). Physical and chemical characteristics of sediments from prawn farms and mangrove habitats on the Clarence River, Australia.Aquaculture. 146: 47–83.
43. Sikoki, F. D. and Veen, J. V. (2004). Aspects of water quality and the potential for fish production of Shiroro Reservoir, Nigeria. Liv. Sys.Sus. Dev. 2, 7pp.
44. Hogan, M.E. and Ward, B.B. (1998). Response of a marine sediment microbial community exposed to 2,4-Dichlorophenoxyacetic acid. Microbial Ecology, 35: 72–82.
45. Si-fa, L., Wan-qi, C., Shu-ming, Z., Jin-liang, Z., Cheng-hui, W., and Gui-juan, C. (2000). Quality analysis of Chinese mitten crab Eriocheir sinensis in Yangchenghu Lake. Zhongguo Shui Chan kexue= Journal of Fishery Sciences of China, 7(3), 71-74.
46. Abulude, F. O., Lawal, L. O., Ehikhamen, G., Adesanya, W. O., and Ashafa, S. L. (2006). Distribution of macrominerals in four prawns from the coastal area of Ondo State, Nigeria. Journal of Fisheries International, 1(2-4), 70-72.
47. Elegbede, I. O. and Fashina-Bombata, H. A. (2013). Proximate and Mineral Compositions of Common Crab Species [Callinectes pallidus and Cardisomaarmatum] of Badagry Creek, Nigeria. Poult Fish Wildlife Sci., 2:1.
48. Ehigiator, F. A. R., and Oterai, E. A. (2012). Chemical composition and amino acid profile of a caridean prawn (Macrobrachiumvollenhovenii) from Ovia river and tropical periwinkle (Tympanotonusfuscatus) from Benin river, Edo state, Nigeria. International Journal of Research and Reviews in Applied Sciences, 11(1), 162-167.

49. Inyang, A., and Effiong, K. (2017). Biochemical Composition of an Estuarine Oyster (Ostrea Tulipa Lamarck), Thais califera Var. coronata (Lamarck) and Senilia senile (Linnaeus) in a Mangrove Swamp of Eastern Obolo, Niger Delta. J Mar Biol Oceanogr 6, 1, 2.
50. Asuquo, F. E., Ewa-Oboho, I., Asuquo, E. F., and Udo, P. J. (2004). Fish species used as biomarkers for heavy metal and hydrocarbon contamination for Cross River, Nigeria. Environmentalist, 24(1), 29-37.
51. Udo, P. and Vivian, N. A. (2012). The proximate and mineral composition of two edible crabs *Callinectes amnicola* and Uca tangeri(Crustecea: Decapode) of the Cross River, Nigeria, Pakistan Journal of Nutrition, 11 (1): 78-82.
52. Varadharajan, D. and Soundarapandian, P.,(2014). Proximate Composition and Mineral Contents of Freshwater Crab Spiralothelphusahydrodroma (Herbst, 1794) from Parangipettai, South East Coast of India. J. Aquac Res Development, 5:2.
53. Nurnadia, A. A., Azrina, A., Amin, I., MohdYunus, A. S., and MohdIzuan Effendi, H. (2013). Mineral contents of selected marine fish and shellfish from the west coast of Peninsular Malaysia. International Food Research Journal, 20(1).
54. Gokoghi, N. and Yerlikaya, P. (2003). Determination of proximate composition and mineral content of blue crab (*Callinectes sapidus*) and Swim crab (*Portunus pelagicus*) caught off the gulf of Antalya. Food Chemistry; 80: 495-498.
55. Jimmy, U. P., & Arazu, V. N. (2012). The proximate and mineral composition of two edible crabs *Callinectes amnicola* and *Uca tangeri* (Crustecea: Decapoda) of the Cross River, Nigeria. Pakistan Journal of Nutrition.
56. Özden, Ö., and Erkan, N. (2011). A preliminary study of amino acid and mineral profiles of important and estimable 21 seafood species. British Food Journal. 113 (4): 457-469.
57. Belitz, H. D., & Grosch, W. (2013). Lehrbuch der lebensmittelchemie. Springer-Verlag.
58. Petitjean, Q., Choulet, F., Walter-Simonnet, A. V., Mariet, A. L., Laurent, H., Rosenthal, P., ... & Gimbert, F. (2021). Origin, fate and ecotoxicity of manganese from legacy metallurgical wastes. *Chemosphere*, *277*, 130337.
59. Martínez-Valverde, I., Periago, M. J., Santaella, M., and Ros, G. (2000). The content and nutritional significance of minerals on fish flesh in the presence and absence of bone. Food Chemistry, 71(4), 503-509.
60. Menzel, C. (2001). The physiology of growth and cropping in lychee. In I International Symposium on Litchi and Longan 558:175-184.Moberg, F., and Rönnbäck, P. (2003). Ecosystem services of the tropical seascape: interactions, substitutions, and restoration. Ocean & Coastal Management, 46(1), 27-46.
61. Adeyeye, E. I. (2008). Amino Acid Composition of the whole body, flesh and exoskeleton of female common West African freshwater crab Sudananautes africanus africanus. Int. J. Food Sci. Nutr.,59, 699–705.
62. Musaiger, A. O., and Al-Rumaidh, M. J. (2005). Proximate and mineral composition of crab meat consumed in Bahrain. International journal of food sciences and nutrition, 56(4), 231-235.
63. Yankson, P.W.A. and Obodai E. A., (1996). Seasonal Changes in biochemical composition of the Mangrove Oyster, Crassostrea roupa(Lamarck) occurring In two coastal water bodies in Ghana. Ghana J. Sci., 31-36, 37-43.
64. Fagbuaro, O., Oso, J., Abayomi, J., Majolagbe, F. A. and Oladapo A. O. (2013). Quality Analysis of Freshwater Crab Cardisomaarmatum and Marine Blue Crab Callinectes amnicola Collected from Yaba, Lagos Nigeria. Nature and Science; 11(8):22.

65. Kpee, F. and Edori, O. S. (2014). Trace metals content in shore crabs (*Cardisoma guanhumi*) from the coastal area of Port Harcourt City, Rivers State, Nigeria.Scholars Research Library, Archives of Applied Science Research, 6 (6):16-21.
66. Vuletić, N., Lušić, J., and Anđelić, I. (2021). Analysis of Manganese Bioaccumulated in Mediterranean Blue Mussel (Mytilus galloprovincialis) from the Bay of Mali Ston (Adriatic Sea, Croatia) during Diarrhetic Shellfish Poisoning Toxicity. Journal of Marine Science and Engineering, 9(5), 451.