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GRADUATE RESEARCH ARTICLE

Morphometric and Heavy Metals Accumulation in the Muscles of Five Demersal Seafoods Sampled in Nigerian Coastal Waters

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ABSTRACT

This study examined the morphometric and heavy metals accumulated in the muscles of five demersal sea-foods: *Parapenaeopsis atlantica, Penaeus monodon, Penaeus notialis*, *Portunus validus* and *Cynoglossus browni* from Nigerian coastal waters. 506 deep frozen samples (at -20^{0}C) each of the five demersal species were taken upon arrival from thirty-one (31) industrial fishing trawler vessels owned by a private fishing company in Lagos, Nigeria. Samples were thawed and morphometric characteristics such as weight, total length, standard length, body depth and carapace length/head length were measured. The heavy metals [Lead (Pb), Iron (Fe), Zinc (Zn), Arsenic (As), Mercury (Hg) and Cadmium (Cd)] were analyzed using 210 Atomic Absorption Spectrophotometer (AAS). The morphometric characteristics revealed that *P. atlantica* and *P. notialis* showed no significant difference in mean values only for their carapace lengths while both species showed statistically different observations for other variables. The order of the heavy metals mean concentration was Zn>Fe>Pb. As and Cd had relatively very low values of <0.01mg/kg while Hg was not detected in all samples. The findings of this study revealed high and increasing values of Zinc in all five demersal species under consideration exceeding maximum limits for FAO/WHO and NIS (Nigerian Industrial Standard). The zinc value of the species appears to be contained in this order; *P. notialis* > *C. browni* > *P. monodon* > *P. validus* >*P. atlantica*. However, Iron value for *P. atlantica* is above the limit of FAO/WHO. Consumption of the species invariably leads to a rise in the Zinc contents in diets and in humans which may cause gastrointestinal disorders, kidney and liver abnormal functioning especially in infants and children while other heavy metals contained in the species do not pose a threat to human health.

Keywords: Heavy metals, Morphometrics, Demersal, Seafoods

1 Introduction

The Nigerian coastal area is the hub of marine fish production and the fishing business constitutes a large source of income for many and is the major source of dietary protein for the rural population. The coastal region has more than 104 species different species of fish of commercial importance [1].

Nigeria has eight (8) coastal states which shares borders with the Atlantic Ocean. These States includes Lagos, Ogun, Ondo, Delta, Rivers, Bayelsa, Akwa-Ibom and Cross Rivers States. Over the years, these states have experienced increased industrialization and high population due to migration of people from rural areas of other states in search of 'greener pastures'. According to UN World Urbanization Prospects [32], Lagos 2021 population is now estimated at 14,862,111. In 1950, the population of Lagos was 325,218. Lagos has grown by 493,779 since 2015, which represents a 3.44% annual change. Other Cities such as Port Harcourt (Rivers State), Uyo (Akwa Ibom State) and Warri (Delta State) just to mention a few are have experienced 4.99%, 5.65% and 5.02% population growth rate in year 2021.

These advancements have also simultaneously polluted the natural environment through industrial and domestic wastes, municipal sewage, dust, pollutants like automobiles and others gets discharged and enter into water bodies and then directly or indirectly get into our food [8]. Exploration and exploitation activities of oil companies such as Shell, Chevron, Texaco etc., in the Coastal region of Ondo State, Nigeria is one major way by which the natural coastal waters of Ondo State is being polluted [28]. Ajani *et al*, [2] further established in his study on the evaluation of the pollution status of Lagos Coastal waters and sediments that anthropogenic activities such as dredging, oil spillages, domestic sewage discharges, sewage dump, biodegradable organic matter and thermal pollution was highlighted in five stations where the study was carried out.

Heavy metals pollution continues to present significant environmental challenge to communities around Lagos lagoon complex, Lagos Nigeria because of the growing number of companies that discharge effluents into the lagoon [23]. In a recent study by Elekima *et al*, [8], Lead (Pb) and Cadmium (Cd) had values above the FAO/WHO permissible limits in seafoods such as periwinkle, shrimps and mudskippers in selected creeks in Rivers State.

Kushoro and Ndimele [18] investigated the following heavy metals; Cu, Zn, Pb and Fe in the water, sediment and in *Oreochromis niloticus* from a section of the Lagos lagoon and discovered that the values of copper and Iron were higher than the limits recommended by WHO, Nigeria's Federal Environmental Protection Agency and United States Environmental Protection Agency and that the values in ologe lagoon, Etegbin and Ijon are increasing. Olaniyi and Popoola [27] in a study of Trace metal concentrations of Surface Sediments and total organic carbon of sediment core in Lagos Coastal waters, Southwest Nigeria stated that recent residential and industrial effluents had triggered the need to continually monitor and assess the hydrochemistry and pollution index of Lagos coastal waters and sediments in Southwest Nigeria.

In 2019, 143 fishing vessels were allowed and licensed to fish marine products within Nigeria's territorial and coastal waters by the Federal Department of Fisheries and Aquaculture under the Ministry of Agriculture [15]. *Penaeus notialis*, *Penaeus monodon, Parapenaeopsis atlantica, Portunus validus* and *Cynoglossus browni* are part of the rich demersal marine fisheries resources caught by both artisanal fishermen, small and industrial trawler operators in Nigeria [25].

Peneaus notialis (Perez-Farfarte, 1967) (Plate 1), also known as *Farfantepeneaus notialis* can be found in Eastern Atlantic: West African Coast from Mauritania to Angola. Western Atlantic: Greater Antilles from Cuba to the Virgin Islands; Atlantic Coast of Middle and South America from S. Mexico (Quintana Roo) to Brazil (S. to Rio de Janeiro). Depth 3 to 100m, rarely as deep as 700m, usually between 3 and 50m. Bottom mud or sandy mud and sandy patches among rocks. Marine; juveniles estuarine. Maximum total length 175mm (male), 192mm (female); maximum carapace length 41mm (male), 48mm (female). The species is also the subject of important fisheries in West Africa, both locally and by foreign trawlers. Aquaculture experiments with this species have been undertaken in Cuba. The total catch reported for this species to FAO for 1999 was 34900t. The countries with the largest catch were Nigeria (27341t) and Senegal (4887t) [13].

Penaeus monodon (Plate 2) is the largest shrimp species globally and has the fastest growth rate among all penaeid species. Nigeria is a maritime state with enormous water resources including fresh, brackish and marine waters. *P. monodon* although not indigenous to West African region but accidentally introduced has become well established in the coastal waters of Nigeria as fishing trawlers and local fishermen catch berried females all year round [4]. Giant tiger prawns are identified by distinct black and white stripes on their backs and tails; on their abdomen, these stripes alternate black/yellow or blue/yellow. Base body colour varies from green, brown, red, grey or blue. These prawns are very large, reaching 330mm or greater in length (largest individual found at 336mm total length) and are sexually dimorphic with females larger than males. At sexual maturity, female carapace lengths range from 47 – 164mm and their total lengths from 164 – 190mm, while male carapace lengths fall between 37 and 71mm, with total lengths of up to 134mm. On average, females weigh 200 - 320g and males weigh 100 – 170g. Giant tiger prawns are nocturnal feeders that often burrow into substrate during the day. They move about the ocean floor searching for food, which is picked up and manipulated by their pereopods and mouthparts. Giant tiger prawns are detritivores and consumers of small invertebrates. They also are prey for many species of fishes and invertebrates [17].

Parapenaeopsis atlantica (Plate 3) is a benthic organism with depth range 1 – 60m, usually 10 – 40m. It is tropical and prefers 27^{o}C; it occurs between 16^{o}N – 35^{o}S, 18^{o}W – 36^{o}E. It is distributed in Eastern Atlantic and Western Indian Ocean: West African Coast from Senegal to Angola and around the South African cape to Mozambique. Common total length: 6.0 to 9.0cm (male); 9.0 to 14.0cm (female). Found on bottom mud or sandy mud marine and estuarine environment with temperature not less than 16^{o}C. Members of the order Decapoda are mostly gonochoric mating behaviour: Precopulatory courtship virtual is common (through olfactory and textile ecces); usually indirect sperm transfer [34].

Portunus validus (Herklots, 1851) (Plate 4) is synonymous to *Neptunus validus* (Herklots, 1851) and *Sanquerus validus* (Herklots, 1851). It is commonly called Smooth swim crab. This is the largest West African swimming crab with a maximum carapace length 9.3 cm and maximum width 19cm. Carapace is smooth and swollen, without transverse ridges. Front bearing 6 rather sharp, triangular teeth (including the inner orbital teeth): anterolateral margin with 8 similar, but slightly wider teeth followed by a sharp lateral spine, which is less than twice as long as last anterolateral tooth. Chelipeds are unequal, smooth, with 3 ridges on the outer surface of palm and 1 on inner surface; palm bearing a single anterodorsal spine: fingers with no distinct ridges. The walking legs are smooth with some grooves on lateral surfaces. Abdomen of male is triangular. The carapace is rather uniformly brownish to greenish gray of khaki colour with a conspicuous large white spot on each side just before the posterolateral margin; upper surface of chelipeds and legs strikingly marbled with purple or blue, contrasting strongly with the rather uniformly coloured carapace. Lower surface of body is uniformly white [12]. The smooth swim crab, *P. validus* occurs off tropical West Africa from Mauritania to Angola and inhabits shallow waters between 0m- 50m. It is found from bottoms consisting of shells, muddy sand, fine sand mud or on shells and mud. It is an economically important crustacean for food, commerce and biological research. Very little information is available on the biology of this species off the Nigerian Coast [19].

Cynoglossus browni (Chabanand, 1949) (Plate 5) has a body that is elongated, snout rounded with a short rostral hook not reaching to vertical through front margin of upper eye; eyes on left side, small with a broad space between them. Maxilla reading back behind upper eye. Dorsal fin rays 115 – 15; anal fin rays 96 – 99; caudal fin rays 12. Eyed side with 2 lateral lines, the midlateral with 84 – 91 scales; scales ctenoid on eyed side, cycloid on blind side. It has eyed side dark brown with a whitish blind side and size could be up to 40cm. Its habitat is benthic on muddy or sandy bottoms of the continental shelf, at depths of 15 – 40, (mainly 15 – 25m). It feeds on a wide range of bottom living invertebrates. It is distributed in West Africa (Congo to Senegal) as well as from the Netherlands Coast [20].

Sakib [31], in a current essay write-up buttressed that the Niger Delta region have failed to adopt best practice strategies for risks mitigation and comply with environmental regulations. This coupled with the failure of the Nigerian Government to enforce the aforementioned environmental regulations contribute towards the unabated environmental contamination, with direct consequences on the surrounding populations' socio-economic wellbeing, human health and the environment. The toxic nature of some heavy metals in aquatic environment invariably affects the organism that lives in the environment; hence poses a greater danger to man as final consumers of some of these affected aquatic organisms [26]. There is a lot of importance for the determination of heavy metals in various environmental segments, such as air, water and soil due to their carcinogenic and toxic nature [22]. Many findings by researchers have being reported in Nigeria and globally on the environmental threats posed by heavy metals. The findings of this

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study will further trigger the call on relevant agencies in Nigeria to act swiftly to curb or reduce the menace of pollution by heavy metals to acceptable limits should there be values that exceeds permissible limits.
As reported by Kushoro and Ndimele [18] of a possible increase in the concentrations of Cu and Fe in a section of Lagos lagoon, it is imperative to launch a study on a much wider area such as the Nigeria coastal waters to ascertain this claim and to know whether or not the increase in heavy metals values is occurring in this coastal area as a whole especially amongst marine demersal species. The aim of this study is to determine the Morphometrics of five demersal seafoods: *Parapenaeopsis atlantica, Penaeus monodon, Penaeus notialis*, *Portunus validus* and *Cynoglossus browni* with a view to give an insight into the biology of the species and to assess the heavy metals (Pb, Zn, Fe, As, Hg and Cd) accumulation in the muscles of the demersal sea foods to ascertain the safety level and health risk associated with the consumption of the seafoods by the public.

2 Materials and Methods

2.1 The Study Area

The Nigerian Coastal waters which falls within Eastern Central Atlantic FAO Area 34. Nigeria is bordered to the North by the Republic of Niger and Chad, to the West by the Republic of Benin, to the East by the Republic of Cameroon and to the South by the Atlantic Ocean. Nigeria has a coastline of approximately 853km facing the Atlantic Ocean. This Nigerian coastline (Figure 1) lies between latitude $4^0 10^1$ to 6^0 20^1 N and longitude 2^0 45^1 to 8^0 35^1 E.

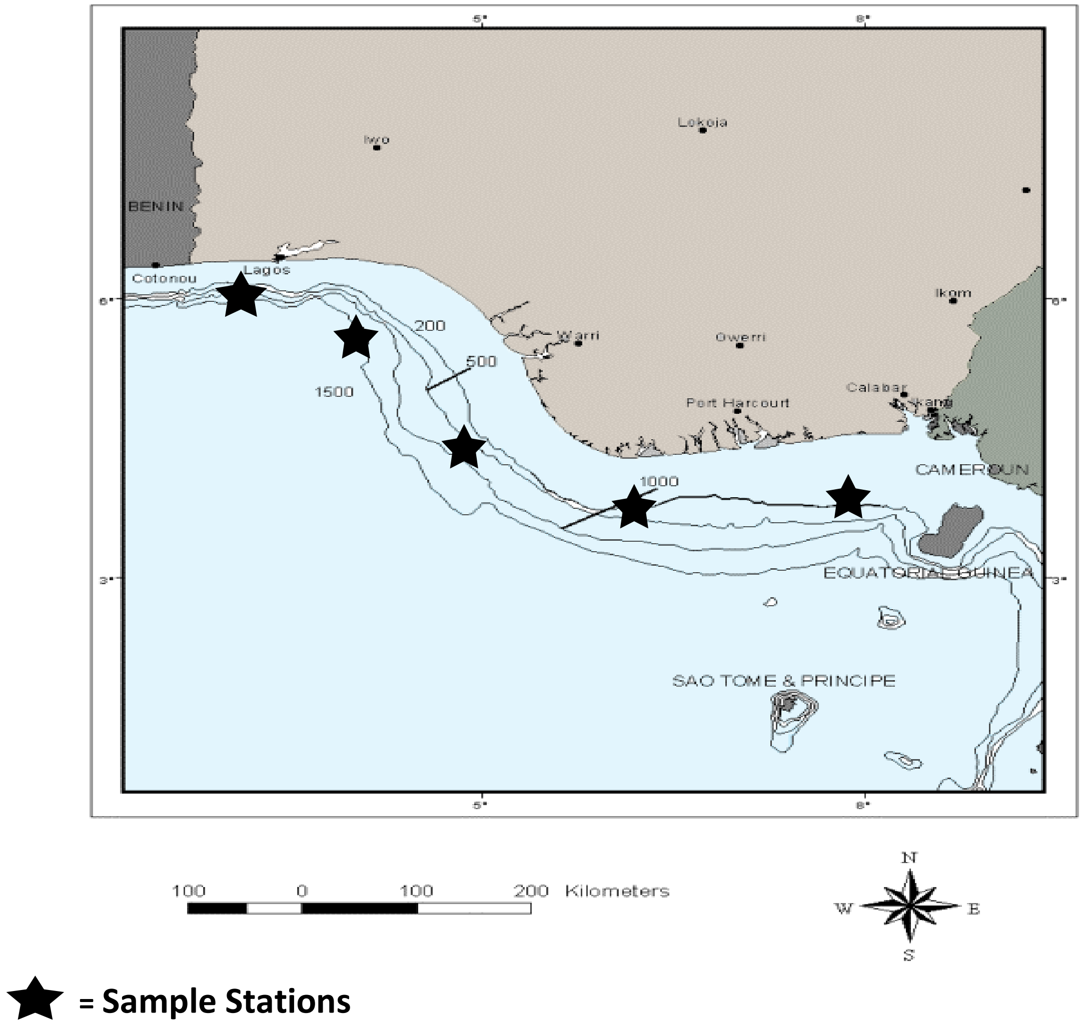

Figure 1*: Map of Nigeria's Coastal waters and Sampling Stations*

The terrestrial portion of this zone is about 28,000km in area, while the surface area of the continental shelf is 46,300km [6]. The Coastal line has eight states it shares borders with. They are Lagos, Ogun, Ondo, Rivers, Delta, Akwa Ibom, Bayelsa and Cross River States. A trawler voyage of sixty (60) days to and fro covers the area and also the eight coastal states.

2.2 Collection of Samples

Deep frozen samples of *Cynoglossus browni* (Nigerian tongue sole), *Parapenaeopsis atlantica* (Brown Shrimp), *Penaeus notialis* (White Shrimps), *Penaeus monodon* (Black tiger Shrimps) and *Portunus validus* (Smooth Swim Crab) were obtained from thirty-one (31) fishing trawlers owned by a private fishing company in Lagos, Nigeria. A total of 506 samples of each species for a period of 6 months collected were thawed.
The Total length (TL), Standard length (SL), Head length (HL), Carapace length (CL), Body depth (BD) were measured with a measuring ruler taken to the nearest 0.1cm as well as the weight of each sample was recorded.
Also, 25g of the muscles of on board frozen *Cynoglossus browni*, *Parapenaeopsis atlantica*, *Penaeus notialis*, *Penaeus monodon* and *Portunus validus* was collected aseptically with the use of a knife upon arrival of a fishing trawler and taken immediately to the laboratory for heavy metals analysis. Samples were caught from Nigerian coastal waters by method of bottom trawling.

2.3 Determination of Heavy Metals

Muscle samples weighing 1.0g of Twenty (20) specimens of each species was crushed into fine powder. It was then placed in 25ml conical flask. 10ml of water was added to it and afterwards 3ml of concentrated hydrochloric acid (HCl) was added to it. It was then digested with 5ml concentrated nitric acid (HNO_3). It was swirled to mix. The mixture was boiled on a hot plate. Water was continuously added to the mixture as it dries off. The mixture was smelt to ensure the acid was burnt off completely. Distilled water was then added to make it up to 100ml. The completely digested sample was filtered and results were read using 210 Atomic Absorption Spectrophotometer (AAS) which uses acetylene gas in its operation. Different lamps were inserted to read the corresponding heavy metals in the sample. Metals such as Lead (Pb), Iron (Fe), Zinc (Zn), Arsenic (As), Mercury (Hg) and Cadmium (Cd) were detected and results were recorded in mg/kg unit

2.4 Statistical Analysis

A Levene's test was conducted for homogeneity. All data collected were subjected to one way Analysis of Variance (ANOVA) using SPSS v 23 and R v 3.6.1. Games and Howell's post HOC tests were used because data were heterogeneous in variances. A further study to determine the species showing significant disparities was done using a Turkey's HSD Post Hoc Test.

3 Results and Discussion

Table 1 presents the morphometric characteristics in terms of the mean and standard error values for the five demersal species considered for this study. *P. atlantica, P. monodon, P. notialis* and *P. validus* had mean carapace lengths of 5.19 ± 0.09, 8.37 ± 0.08, 5.22 ± 0.11 and 14.77 ± 0.16 respectively while *C. browni* had a mean carapace length of 7.66 ± 0.11. *P. atlantica, P. monodon, P. notialis, C. browni* and *P. validus* had mean body depths of 1.17 ± 0.02, 3.38 ± 0.04, 2.08 ± 0.04, 10.23 ± 1.28 and 6.96 ± 0.08 respectively. It further highlighted that *P. atlantica, P. monodon, P. notialis, C. browni* and *P. validus* mean body weights; 9.42 ± 0.26, 96.79 ± 2.38, 26.82 ± 1.34, 411.09 ± 15.27 and 284.09 ± 7.34 respectively. Also *P. atlantica, P. monodon, P. notialis and C. browni* had total lengths; 11.56 ± 0.12, 22.55 ± 0.19, 14.71 ± 0.25 and 46.32 ± 0.62 respectively. *P. atlantica, P. monodon, P. notialis and C. browni* had standard lengths; 9.91 ± 0.12, 18.68 ± 0.16, 12.09 ± 0.24 and 42.84 ± 0.58 respectively. From this table, *Parapenaeopsis atlantica* was observed to have the least carapace length which is closely followed by *P. notialis*.

Table 2 reveals Games-Howell's Post Hoc Test for the Morphometric characteristics since the observations were heterogeneous in variances. *P. atlantica* and *P. notialis* showed no significant difference in mean values only for their carapace lengths (5.19 and 5.22cm) while both species showed statistically different observations for other variables (body depth, weight, Total length and standard length). *P. monodon, P. validus* and *C. browni* had statistically significant result for other variables.

Figure 1 is a grouped bar chart for the mean content of Iron, Zinc and Lead for the species in this study showing the highest and lowest values as stated above. Mercury (Hg) was not detected (ND) in any of the species while Arsenic (As) and Cadmium (Cd) were observed to be < 0.01mg/kg. All the species had Lead (Pb), Iron (Fe) and Zinc (Zn) in different proportions. This resulted in a conduct of an analysis of variance to ascertain the similarities of the Iron, Lead and Zinc composition by the species.

Figures 2, 3 and 4 are graphs that show the mean levels of Lead (Pb), Iron (Fe) and Zinc (Zn) concentrations respectively in mg/kg unit in all the five demersal seafoods under consideration. The mean Pb concentrations ranged from 0.119mg/kg in *P. monodon* to 0.151mg/kg in *P. notialis* while mean Fe concentrations ranged from 2.356mg/kg in *P. monodon* to 2.700mg/kg in *P. atlantica* and mean Zn concentrations ranged from 8.600mg/kg in *P. atlantica* to 9.129mg/kg in *P. notialis.*

Table 4, shows the summary of the observations made on the five demersal species. The table revealed the mean, standard deviation, standard error, minimum and maximum values of the heavy metals. The highest value of Zinc was found in *C. browni* to be 9.870mg/kg while the lowest value was found in *P. atlantica* to be 7.380mg/kg. The highest value of Iron was also found in *C. browni* to be 3.970mg/kg while the lowest value was found to be the same in both *P .monodon* and *P. notialis* (1.960mg/kg). The highest value of Lead was found in *P. notialis* to be 0.5mg/kg while the lowest value is the same in *P. monodon*, *P. notialis*, *C. browni* and *P. validus* (0.1mg/kg).

A Levene's test for homogeneity (Table 3) to ascertain the uniformity in the distribution of the observations for the five species showed that the composition of Iron and Zinc was uniformly spread in the species, while Lead were not uniformly spread for all the species. This resulted in further study to determine the species showing significant disparities using a Turkey's HSD Post Hoc Test (Table 5), since the distribution of the observations were not significantly different. In Table 5, Pb had values 0.149 ± 0.005 for *P. atlantica,* 0.119 ± 0.006 for *P. monodon,* 0.151 ± 0.020 for *P. notialis,* 0.138 ± 0.007 for *C. browni* and 0.144 ± 0.008 for *P. validus*. Fe had values 2.700 ±0.071 for *P. atlantica*, 2.256 ± 0.064 for *P. monodon*, 2.324 ± 0.080 for *P. notialis*, 2.431 ± 0.102 for *C. browni* and 2.415 ± 0.089 for *P. validus.* Zn had values 8.680 ± 0.123 for *P. atlantica*, 8.971 ± 0.114 for *P. monodon*, 9.129 ± 0.116 for *P. notialis*, 8.997 ± 0.109 for *C. browni* and 8.855 ± 0.084 for *P. validus*. As and Cd for all the species had values < 0.01 while Hg for all the species was not detected.

It also showed that *P. atlantica* statistically significantly contained higher Fe than *P. monodon* and *P. notialis*. The value of Iron contained in *P. atlantica* cannot be said to be significantly higher than those observed in in *C. browni* and *P. validus*. These tests were all conducted at the 95% confidence interval. However, the Fe value of 2.700 ±0.071 for *P. atlantica* was higher than the 2.5mg/kg acceptable limit by FAO/WHO. Also, the Zn values for all the species under study had values much higher than the recommended FAO/WHO value of 1mg/kg and Nigerian Industrial Standard (NIS) value of 0.5mg/kg.

Table 1: *Descriptive statistics for Morphometrics characteristics of the Species*

Parameters	*Parapenaeopsis atlantica* (Brown Shrimps)	*Penaeus monodon* (Giant Black Tiger Shrimps)	*Penaeus notialis* (White Shrimps)	*Cynoglossus browni* (Nigerian Tongue Sole)	*Portunus validus* (Smooth Swim Crab)
Carapace / Head length (cm)	5.19 ± 0.09	8.37 ± 0.08	5.22 ± 0.11	7.66 ± 0.11	14.77 ± 0.16
Body depth(cm)	1.17 ± 0.02	3.38 ± 0.04	2.08 ± 0.04	10.23 ± 1.28	6.96 ± 0.08
Weight (g)	9.42 ± 0.26	96.79 ± 2.38	26.82 ± 1.34	411.09 ± 15.27	284.09 ± 7.34
Total length (cm)	11.56 ± 0.12	22.55 ± 0.19	14.71 ± 0.25	46.32 ± 0.62	Nil
Standard length (cm)	9.91 ± 0.12	18.68 ± 0.16	12.09 ± 0.24	42.84 ± 0.58	Nil

N.B: Each cell contains means ± std. error, Head length applies for Cynoglossus browni

Table 2: *Games-Howell Post Hoc Test for the Morphometric characteristics*

Parameter	*P. atlantica*	*P. monodon*	*P. notialis*	*C. browni*	*P. validus*
Carapace/ head length (cm)	5.19^{a}	8.37^{c}	5.22^{a}	7.66^{b}	14.77^{d}
Body depth (cm)	1.17^{a}	3.38^{c}	2.08^{b}	10.23^{e}	6.96^{d}
Weight (g)	9.42^{a}	96.79^{c}	26.82^{b}	411.09^{e}	284.09^{d}
Total length (cm)	11.56^{a}	22.55^{c}	14.71^{b}	46.32^{d}	-
Standard length (cm)	9.91^{a}	18.68^{c}	12.09^{b}	42.84^{d}	-

a,b,c,d,e Means along the same row with different superscript are significantly different at p-value =0.05
Head length applies for C. browni

Table 3: *Levene's test for homogeneity of variance for Heavy metal accumulation in the five demersal seafoods*

Heavy metal	Levene statistic	df1	df2	sig.	Remark
Lead composition	2.894	4	95	0.026	Significant
Iron composition	0.643	4	95	0.633	Not significant
Zinc composition	1.292	4	95	0.279	Not significant

N.B. p – value = 0.05

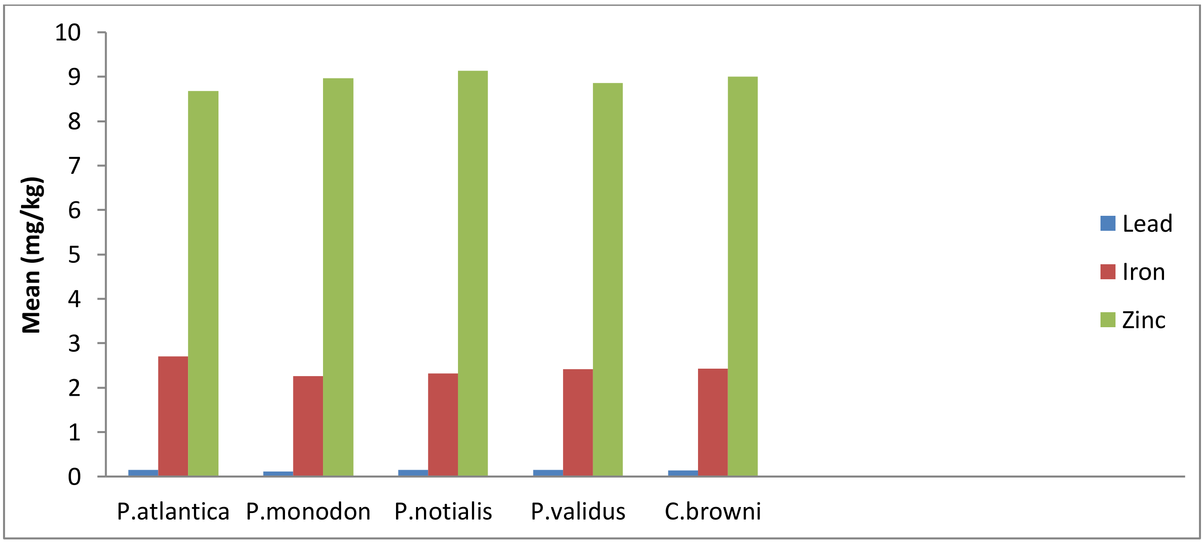

Figure 2: *Heavy metal contents in the demersal species*

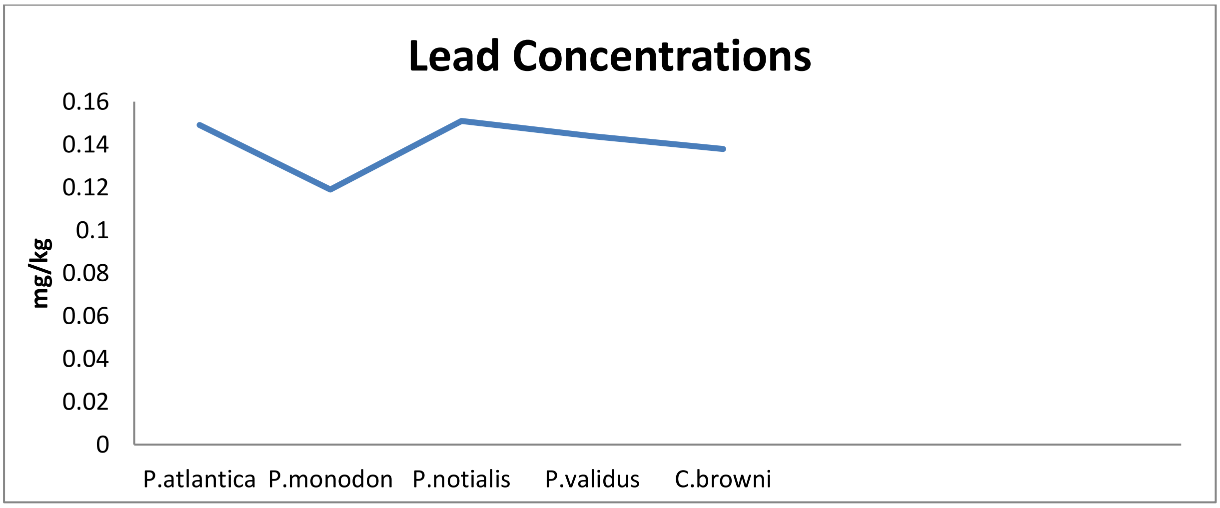

Figure 3: *Lead Composition in the demersal Species*

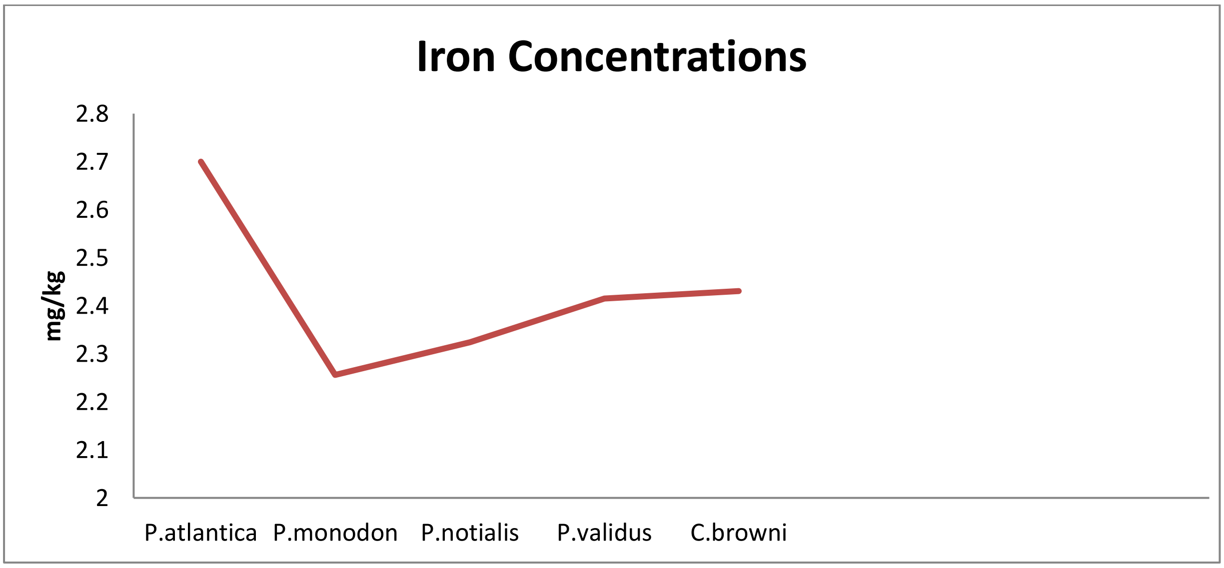

Figure 4: *Iron composition in the demersal species*

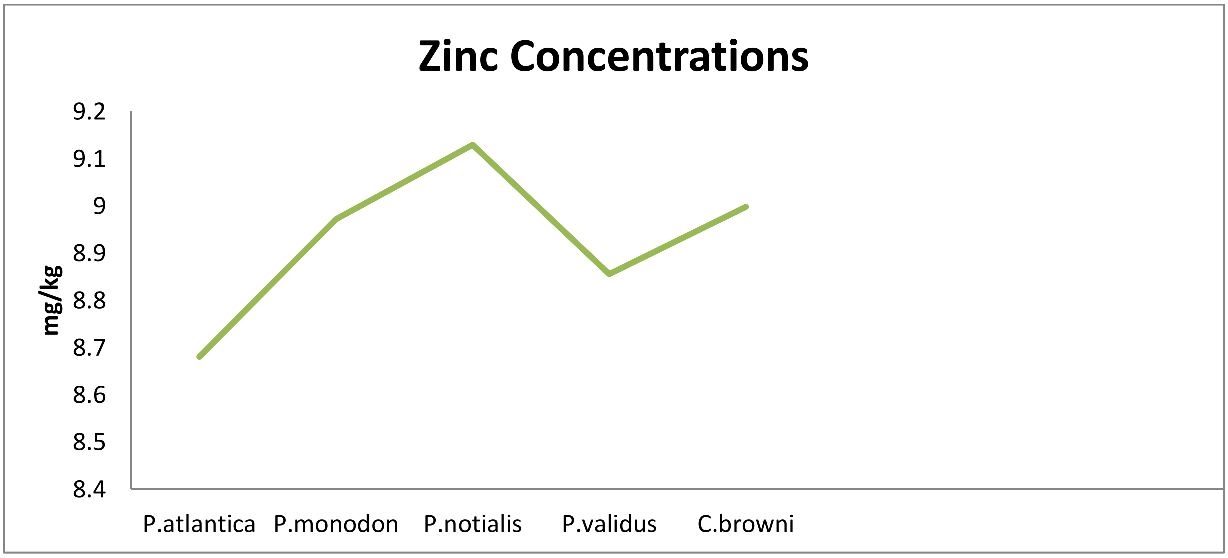

Figure 5: *Zinc composition in the demersal species*

Table 4: *Summary for heavy metal composition in the muscles of the demersal species*

		Lead	Iron	Zinc	Arsenic	Mercury	Cadmium
P. atlantica	Mean	0.149	2.700	8.680	<0.01	ND	<0.01
	Std. deviation	0.022	0.317	0.552	<0.01	ND	<0.01
	Std. Error	0.005	0.071	0.123	<0.01	ND	<0.01
	Minimum	0.110	2.110	7.380	<0.01	ND	<0.01
	Maximum	0.190	3.180	9.440	<0.01	ND	<0.01
P. monodon	Mean	0.119	2.256	8.971	<0.01	ND	<0.01
	Std. deviation	0.026	0.285	0.511	<0.01	ND	<0.01
	Std. Error	0.006	0.064	0.114	<0.01	ND	<0.01
	Minimum	0.100	1.960	8.100	<0.01	ND	<0.01
	Maximum	0.200	3.140	9.660	<0.01	ND	<0.01
P. notialis	Mean	0.151	2.324	9.129	<0.01	ND	<0.01
	Std. deviation	0.090	0.359	0.517	<0.01	ND	<0.01
	Std. Error	0.020	0.080	0.116	<0.01	ND	<0.01
	Minimum	0.100	1.960	7.810	<0.01	ND	<0.01
	Maximum	0.500	3.240	9.630	<0.01	ND	<0.01
C. browni	Mean	0.138	2.431	8.997	<0.01	ND	<0.01
	Std. deviation	0.029	0.454	0.488	<0.01	ND	<0.01
	Std. Error	0.007	0.102	0.109	<0.01	ND	<0.01
	Minimum	0.100	2.010	8.060	<0.01	ND	<0.01
	Maximum	0.210	3.970	9.870	<0.01	ND	<0.01
P. validus	Mean	0.144	2.415	8.855	<0.01	ND	<0.01
	Std. deviation	0.037	0.399	0.378	<0.01	ND	<0.01
	Std. Error	0.008	0.089	0.084	<0.01	ND	<0.01
	Minimum	0.100	1.970	7.850	<0.01	ND	<0.01
	Maximum	0.220	3.500	9.470	<0.01	ND	<0.01

Note: Unit for Heavy metals is in mg/kg. ND= Not Detected

Table 5: *Turkey's HSD Post HOC test for Heavy Metals Accumulation with FAO/WHO and NIS Limits*

Heavy metal (mg/kg)	Species					[14]	[24]
	P. atlantica	***P. monodon***	***P. notialis***	***C. browni***	***P. validus***		
Pb	0.149 ± 0.005[a]	0.119 ± 0.006[a]	0.151 ± 0.020[a]	0.138 ± 0.007[a]	0.144 ± 0.008[a]	0.3	0.2
Fe	*2.700 ±0.071[b]	2.256 ± 0.064[a]	2.324 ± 0.080[a]	2.431 ± 0.102[ab]	2.415 ± 0.089[ab]	2.5	
Zn	*8.680 ± 0.123[a]	*8.971 ± 0.114[ab]	*9.129 ± 0.116[b]	*8.997 ± 0.109[ab]	*8.855 ± 0.084[ab]	1.0	1.0
As	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.0	1.0
Cd	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	2.0	
Hg	ND	ND	ND	ND	ND		0.5

[a,b] Means along the same row with different superscript are significantly different at p-value =0.05
*Pb = Lead, Fe = Iron, Zn = Zinc, As = Arsenic, Cd = Cadmium, Hg = Mercury. ND= Not Detected * means the values exceeded total acceptable limit*

Plate 1: *Penaeus notialis*

Plate 2: *Penaeus monodon*

Plate 3: *Parapenaeopsis atlantica*

Plate 4: *Portunus validus*

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Plate 5: *Cynoglossus browni*

Five (5) morphometric characters of five (5) demersal species was taken into account in this present study except for *P. validus* that was exempted from both Total length (TL) and Standard length (SL) and six (6) heavy metals was analyzed with a view to assess the bio-integrity of the species. A study by Rajagopal Santhanam, *et al* [30] investigated the relationship between fifteen (15) morphometric characters of *P. monodon* of Cultured and wild males and females. Species used for this present work were all from the wild and samples were collected in a deep frozen state and then thawed to enable accurate reading of morphometric features.

In a similar study off Lagos Coast by Lawal-Are and Bilewu [19] on *Portunus validus*, after examining 618 specimens found the weight to be from 82.3g to 694.0g while in this present study, the weight of the 506 specimens of *Portunus validus* ranged from 130g to 450g.

It is suggested that benthic fish are likely to have higher heavy metal concentrations than fish inhabiting the upper water column because they are in direct contact with the sediments and their greater uptake of heavy metal concentrations from zoo-benthic predators. Zhao, *et al* [35] found that *Cynoglossus gracilis* had the lowest level of metal accumulation among investigated species despite that it is a typical benthic fish. El-Moselhy *et al* [9] reported weak or no support for this suggestion, where variations between pelagic and benthic organisms were detected only as high concentration of iron (Fe) in the gills of the benthic fish *Synodus sp*. However, this present study did not put into account pelagic or mid-water species but the highest heavy metal mean value for the demersal species was observed in Zinc (Zn) for *P. notialis* to be 9.129mg/kg. Other values of Zn are *P. atlantica* 8.680mg/kg, *P. monodon* 8.971mg/kg, *C. browni* 8.997mg/kg and *P. validus* 8.855mg/kg which is worrisome as it exceeds FAO/WHO limit of 1.0mg/kg and NIS limit of 0.5mg/kg. It also implies there is an activity going on in the environment amongst these demersal species that has contributed to these high zinc values. Emmanuel *et al*, [11] reported the order of metal concentrations in the flat fishes in this order Zn>Cu>Pb>Cd. Lead was checked and found to be below detection limit. Similarly, Zinc was found with the highest value in a decreasing order Zn>Fe>Pb.

The mean Iron content for all the five species were within the FAO/WHO limit except for the Iron value is 2.700 ±0.071 mg/kg for *P. atlantica* which is slightly above the 2.5mg/Kg limit of FAO/WHO. The heavy metals detected in this present study could be as a result of oil/ petroleum contamination as reported by Emmanuel and Adedigba [5].

In a study by Prabhu, *et al* [9], it was discovered that the mean concentration of metals in *P. monodon* was Pb>Fe>Cd>Zn>Cu>Cr in pre-monsoon and Pb>Fe>Zn>Cd>Cu>Cr in post-monsoon. Also, Emmanuel and Adedigba [10] revealed that heavy metals in male *Portunus validus* has a decreasing order of Fe>Cr>Zn>Cu>Cd>Co>Pb while in this present study, the order of the mean concentration analyzed in the muscles of *P. validus* as well as in all species was Zn>Fe>Pb. Arsenic (As) and Cadmium (Cd) had relatively low values of <0.01mg/kg while Mercury (Hg) was not detected in all samples. An analysis of variance test on the mean values of the heavy metals showed no significant result for observed Lead and Zinc values for the five species. This however, is not the case for the composition of Iron for the five species.

The levels of Cd in the fish flesh of five fishes in a study by Mohammed, [21] are all lower than the European Community (regulation (EC) N^0 1881/2006) which is in the order of 0.05mg/kg of wet weight for muscle meat of fish. Though Cd is a nonessential element and is considered one of the most toxic elements to humans, fishes and environment due to its capability of producing a chronic toxic effect even at low concentrations. The lowest concentration of Cd (0.11 µg/g) was detected in the flesh of *Clarias angullaris* , while the highest concentration of 1.03 µg/g was observed in the flesh of *Synodontis budgetti* as stated by Akan *et al* [3] while this study showed that Cd had low values of < 0.01 mg/kg for all species under study.

According to Ashraf and Mian [2], the average level of Mercury detected in Grouper fish *Epinephelus microdon* and Green Tiger Prawn *Penaeus semisulcatus* was found to be 0.43 ± 0.07µg/g and 0.37 ± 0.05µg/g respectively. Djedjibegovic *et al* [7] recorded the highest concentration of heavy metals (Cd, Hg and Pb) analyzed in his study of commercial fish and seafoods products in Hg while Hg was not detected in all species of this present study.

The highest mean level of Arsenic reported by Ashraf and Mian [5] amongst the fish species in his study was found in Rabbit fish (*Siganus canaliculatus)* to be 0.57 ± 0.40µg/g while amongst the shrimp species was found in Green Tiger Prawn (*Penaeus semisulcatus)* to be 0.29 ± 0.03µg/g. However, the level of Arsenic of all demersal species in this study was found to be <0.01mg/kg. This does not constitute any health problem as it is below the FAO/WHO and NIS limits.

The Pb values in all demersal species in this study were below FAO/WHO limit hence do not pose a threat to human health. This does not concur with the recent findings of Elekima, *et al* [8] of a high value of Pb exceeding FAO/WHO permissible limit in his study of some heavy metals in selected seafoods (shrimps) directly from the creeks in Rivers State, Nigeria. In as much as Pb had varying values for all species in this study, Pb was examined and not detected by Kazim [16].

The Zinc value of 9.129 ± 0.116 mg/kg for *P. notialis* in this study is close to the zinc value of 9.08 ± 0.89 mg/kg in the muscle of *Carassius carassius* as reported by Kazim [16] in his study of Heavy metals in edible portions and other organs of selected Freshwater fish species. The zinc value of the species appears to be contained in this decreasing order *P. notialis* > *C. browni* > *P. monodon* > *P. validus* >*P. atlantica.* Zinc is regarded as an essential heavy metal whose low values are harmless but high values leads to health issues such as gastrointestinal disorders, Kidney and liver abnormal functioning especially in infants and children. Source of zinc are Oil refining, plumbing and brass manufacturing [22]. Benthic species are known to accumulate heavy metals from water and sediments [33]. This may be the reason for the high values of heavy metals observed in this study. The seafoods are sold fresh, whole frozen, processed, smoked and as value added products in Nigeria or exported.

4 Conclusion

This study revealed that the species had very high mean Zinc values; *P. atlantica* 8.680mg/kg, *P. monodon* 8.971mg/kg, *P. notialis* 9.129mg/kg, *C. browni* 8.997mg/kg and *P. validus* 8.855mg/kg which is worrisome as it exceeds FAO/WHO and NIS limits. It may imply some anthropogenic activities such as Oil refining, plumbing and brass manufacturing may be going on in and around the Nigerian coastal waters that has contributed to these high values. The order of the mean concentration of heavy metals analyzed in the muscles of the Species was Zn>Fe>Pb. Arsenic (As) and Cadmium (Cd) had relatively very low values of <0.01mg/kg while Mercury (Hg) was not detected in all samples. The zinc value of the species appears to be contained in this order *P. notialis* > *C. browni* > *P. monodon* > *P. validus* >*P. atlantica.* The mean Iron content for all the five species were within the limit except for the Iron value of 2.7mg/kg for *P. atlantica* which is slightly above the 2.5mg/kg limit of FAO/WHO. Consumption of these species could lead to ill health especially in infants and children while other heavy metals contained in the species do not constitute a threat to human health. It is worthy of note that these demersal seafoods are caught and landed by various industrial fishing trawlers and artisanal fishermen in Nigeria which are either sold locally or exported. Having established the toxicity and harmful effects of heavy metals to human health, it is expedient that relevant agencies in Nigeria act swiftly to increase the awareness of the health problems caused by heavy metals, proactively monitor the activities of companies and households that indiscriminately discharge effluents into its coastal waters and to ensure strict compliance with both local and international environmental laws in order to protect the lives of the people.

5 Declarations

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5.4 Competing interests

The authors declare no competing interests.

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