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Bioaccumulation of heavy metals in silver catfish (*Chrysichthys nigrodigitatus*) and tilapia fish (*Oreochromis niloticus*) from the brackish and freshwater in South-West, Nigeria

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Abstract

Background: *Chrysichthys nigrodigitatus* (CN) and *Oreochromis niloticus* (ON) health status were investigated in Asejire Reservoir (AR) and Lagos Lagoon (LL), South-west Nigeria. Fish samples collected were separated into sexes. Growth pattern {length (cm); weight (g), Isometric index, condition factor (K)} were measured. Heavy metals (lead (Pb), iron (Fe), zinc (Zn), copper (Cu), and chromium (Cr) in ppm concentrations were determined in Lagos Lagoon and Asejire reservoir.

Results: Fish samples ranged at one male to one or two females. No significant difference in length and weight of *O. niloticus* between locations. Significant difference in weight occurred in *C. nigrodigitatus* between locations; highest condition factor was recorded in Asejire Reservoir *O. niloticus*, (ARON); lowest condition factor was observed in Asejire Reservoir *C. nigrodigitatus* (ARCN) as this indicated a negative allometric value, normal in Bagridae species. Male species possessed higher condition (K)—factor than female species within locations, between locations, between species, and within species, female *C. nigrodigitatus* having higher condition factor than male ARCN. Highest isometric value occurred in ARON and lowest in Lagos Lagoon *C. nigrodigitatus* (LLCN). Male ARON had highest isometric value, and *O. niloticus* species had higher isometric value ($b \leq 3$) and positive allometric ($b > 3$); and *C. nigrodigitatus* has negative allometric ($b < 3$). Heavy metals Zn had highest value, while Cr ranked lowest value for ARON. Lagos Lagoon *O. niloticus* (LLON) Zn had highest value while Pb had lowest value. LLCN heavy metals determined revealed Zn had highest value, while Cr had lowest value; and ARCN heavy metals determined revealed Zn had highest value, and Cr had lowest. In all, Zinc (Zn) was top-ranked.

Conclusion: Results indicate niche response and performance as species specific; while environmental influence and stressors, food availability and reproduction factors contribute to well-being of fish. The heavy metals influence on the fish species is of public concern to man to avoid food poisoning.

Keywords: *Chrysichthys nigrodigitatus*, *Oreochromis niloticus*, Growth status, Environments, Heavy metals

Background

The physical and chemical properties of water greatly influence the uses, the distribution and richness of biota (Gebrekios, 2016). The aquatic environment encompasses a wide variety of parameters, virtually all of which influence the maintenance of homeostasis, essential for growth and reproduction of fishes. These if altered

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beyond acceptable limits may pre-dispose to, or cause disease. Abiotic and biotic factors for the environment with which the fish interrelate include; temperature, intensity and periodicity of light (including shading and background line); chemical composition of the water, its biological content, the availability of space and food, and frequency of fright stimuli i.e. moving shadows (Taylor, 1997). Anthropogenic condition of aquatic environment which may occur naturally or from human interference can make fish which are naturally safe to be unsafe (Abidemi-Iromini, 2019).

Indiscriminate disposal of waste through municipal communities, and industrialization has contributed immensely to pollution condition of the aquatic environment with believe that the environment will balance up the confluence of interactions in the chemical and biological relationships. The waste load results in an environment heavily laden with micro-organisms, some of which are facultative and pathogenic in nature, and other can be obligate and result also in pathogenic condition, (Kristina et al., 2014). These contaminations from aquatic environment due to varying mis-use have indirect detrimental effect on output of such environment being on economic losses, and health impairment. Becoming disease carrier as that may have been exposed to contaminants (Abidemi-Iromini, 2019; Koenig et al., 2005). The synergy of chemical substances such as ammonia, sulphur, phosphorus, and nitrate; nitrite amidst other physical and biological processes with contaminants, in the aquatic environments can intensify the toxicity experienced within such environments and hence, pathogenic manifestation can be experienced (Koenig et al., 2005).

Pollution in the fish aquatic environment

Fish being sensitive to xenobiotics can be used as ecological indicator; they are highly digestible animal protein source. *Chrysichthys nigrodigitatus* and *Oreochromis niloticus* are fish of economic importance in gulf of Guinea. In Nigeria, the fish species are found in the inland waters and Lagoons. Unguided aquatic environment usage, urbanization and anthropogenic pollutants cause aquatic ecosystem degradation resulting in destruction of fish breeding site, and depletion of fish stock. This is a challenge mitigating quality and quantity of fish available for human utilization (Abidemi-Iromini et al., 2019). Hence, pollutants influence aquatic live as they accumulate different concentration of heavy metals thereby depleting the quality of fish, which are major protein rich food item (Ekeanyanwu et al., 2015).

Metals are very important in environmental research owing to their impact on human health; and are known to form materials that are potentially toxic to the environment (Chi et al., 2007; Turkmen & Ciminli, 2007). The

anthropogenic effects of heavy metal on other aquatic life are less studied (Guerin et al., 2011). Concentrations of heavy metals in sediment increase as organic material increases. Pollutants concentrations in sediments increased with decrease in particle size (Ipeaiyeda & Onianwa, 2018). Therefore, pollution of aquatic environment by inorganic chemicals has been considered a major threat to the aquatic lives. Effluents of pesticides and fertilizers used in agriculture and effluents of industrial activities and runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals (UNEP, 2016).

Heavy metals have on a long run effect, deteriorating impact on aquatic organisms and environment. Mercury, cadmium, selenium, chromium, silver, lead, among others are deleterious to fish health; as some others may cause corrosion (e.g. zinc, lead); some results in a secondary harm through complex interaction, (e.g. Influence of arsenic to catalysts). Trace metals such as zinc, copper and iron, play a biochemical role in life processes of all aquatic plants and animals; and are important in aquatic environment in trace amount (Dürllgen, 2001). According to Ferrara et al (2000) reported that, copper and lead can occur from industrial wastes as well as algacides; chromium and cadmium from electroplating.

Chromium makes fish experienced reduced growth, chromosomal aberrations, reduced disease resistance, and morphological changes. Chromium had been reported to inhibits growth in duckweed and algae, reduces fecundity and survival of benthic invertebrates (Harmon & Wiley, 2010). Silver bio-magnifies in some aquatic invertebrates, but is highly toxic to aquatic organisms. Elevated concentrations of silver can cause larval mortality, developmental abnormalities, and reduced larval growth in fish (Authman et al., 2015).

Cadmium is associated with increased mortality; and it affects respiratory functions, muscle contractions, growth reduction, enzyme levels and reproduction. It is highly toxic to fishes, as it causes cancer and mutation in fish, and bio-accumulates at all trophic levels, and fish exposed to high levels of lead exhibit wide-range of effects including muscular and neurological degeneration and destruction; growth inhibition, mortality, reproductive problems, and paralysis; all which in turns reduces fisheries production and resources (Wu et al., 2016).

The study aims to investigate level of heavy metal in *Oreochromis niloticus* and *Chrysichthys nigrodigitatus* collected from Asejire Reservoir and Lagos Lagoon respectively for public health purposes. Hence, hypothesis to be tested suggested no significant difference in the heavy metal status within the same species from the two environments; and between the two fish species from the same environment.

Methods

Description of study areas

The study was carried out in two different environments (zones): Asejire Reservoir on River Osun in Oyo State and Lagos Lagoon in Lagos State.

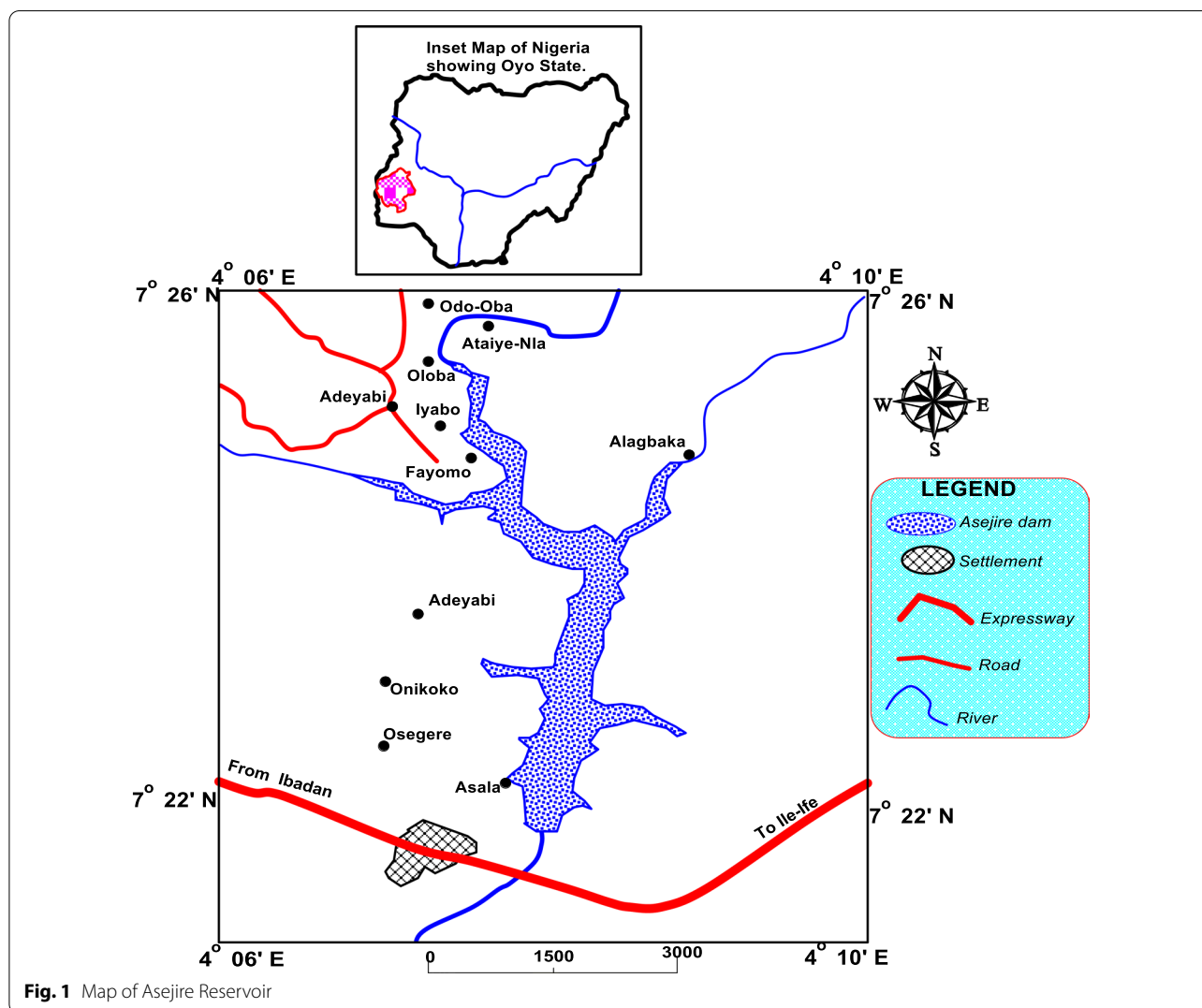
Asejire reservoir

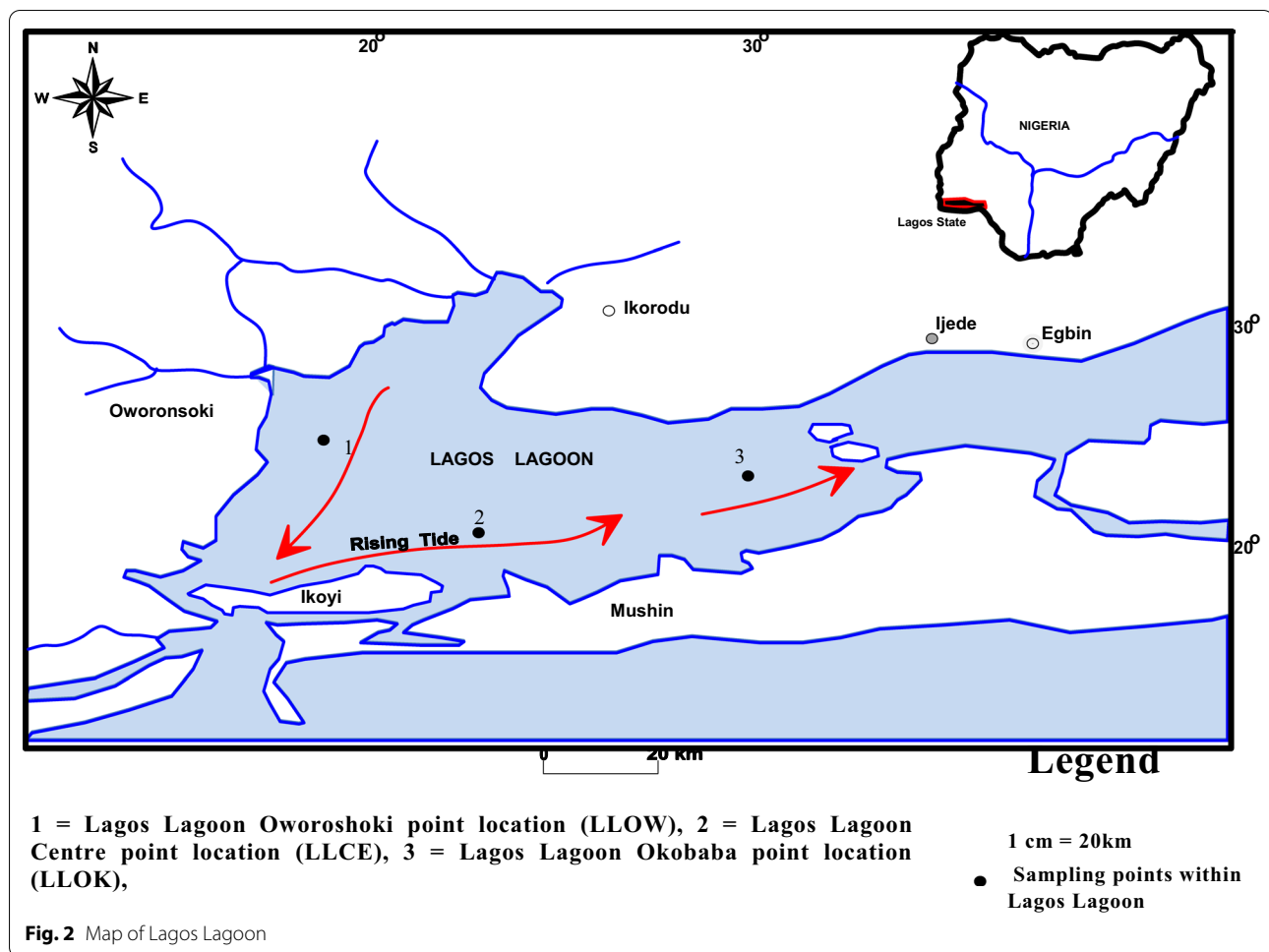
Osun River was dammed at Asejire to form Asejire Reservoir in Egbeda Local Government Area of Oyo State, Southwestern Nigeria (Fig. 1). It is a man-made reservoir located 30 km East of Ibadan, Oyo state (Ayoade et al., 2006). The Reservoir lies between longitudes 4E and 4°07' E and latitude 7° N and 7°21' N. It is bi-furcated into two unequal arms; the left longer arm is fed by Rivers Oba and Osun while the right is supplied by River Agboiro (Adebisi, 1981). The catchment area in the reservoir is 7800 km² land the impounded area is 2342

hectares. It has a rainy season (April–October) with a monthly water mean of 10.3–15.9 mm while dry season is between (November–March) with water mean of 3.78–4.2 mm. The reservoir flows approximately 5 km from its source before breaking into series of rivers and streams (Anetekhai, 1997).

Lagos Lagoon

The Lagos Lagoon (Fig. 2) is part of the continuous system of lagoons and creeks that are found along the coast of Nigeria from the border with the Republic of Benin to Niger-Delta. This lagoon bordering the Lagos Island is located between longitude 30°10' and 30°4' SE and latitude 60°5' and 60°36' N. (Sogbanmu, et al., 2016) reported that Lagos Lagoon has a surface area of 208km², open, tidal and brackish; and is the largest among other lagoon systems of the Gulf of Guinea. It is





connected and non-parallel to Gulf of Guinea coastline over 237 km. Lagos lagoon stretches for about 257.49 km from Cotonou in the Republic of Benin to the Western edge of the Niger-Delta. The lagoon borders the forest belt and receives input from a few important large rivers draining more than 103,626 km of the country. However, Ajao (1996), estimated that the area of the lagoon is 150.56 km². It cuts across the Southern part of the metropolis, linking the Atlantic Ocean (in the West and South) and Lekki lagoon (in the East). It is tidal and shallow with an average depth of 1.5 m except at channels that are continually dredged to accommodate heavy water traffic (Adejare et al., 2011). The Lagos Lagoon receives fresh water from fresh water source (rivers) like Yewa, Ogun, Ona and Osun all year round (Ajao et al., 1996; Asseez et al., 1974) with increase in rainfall. Other source of water influx into the Lagoon system include: Aye, Solodo, Osun, Mosafejo, Owa and Sunmoge (Enai-kele & Olutayo, 2010). Lagos lagoon consists of three main segments: Lagos Harbour, the Metropolitan end and Epe division segments.

Field work duration

Monthly study was carried out on Lagos Lagoon and Asejire Reservoir from January 2012 to December 2013 (2 wet/rainy seasons and 2 dry seasons) during which some ecological determinations were carried out.

Fish sampling

O. niloticus and *C. nigrodigitatus* fish species were randomly collected through the assistance of local fisherman using cage traps and locally made set nets having multiple mesh sizes; within Asejire Reservoir and Lagos Lagoon. Fishes collected look visually health. A total of two hundred and eighty-eight fish were collected comprising of seventy-two fish samples per species per location respectively. Fish collected were immediately transported to the laboratory in a 25 L plastic container containing water from sites of collection to reduce incidence of stress on the fish. Fish samples from Lagos Lagoon were transported to Marine Sciences Laboratory in University of Lagos, while samples collected from Asejire reservoir

were transported to Fisheries and Aquaculture Technology laboratory, in The Federal University of Technology, Akure. Samples collections and analysis were carried out according to guidelines by Nickum et al. (2004).

Morphometric measurement on length and weight of fish

Total length (TL) and Standard Length (SL) (cm) of fish samples to nearest 0.01 cm were determined using a graduated board; and Weight (W) (g) of the fish samples were measured to the nearest 0.01 (g) using top load electronic balance, Model MP 2002 and Mettler Toledo electronic weighing balance (Model; PB8001).

Length/frequency distribution

The length and frequency of occurrence of fish were recorded among fish (*O. niloticus* and *C. nigrodigitatus*) samples collected throughout the study period.

Growth pattern relationship

Length–Weight Relationship (LWR) of fish species was determined in *O. niloticus* and *C. nigrodigitatus* regardless of sex and year class using the equation (Pauly, 1983):

$$W = aL^b.$$

where W =weight (g) of fish, L =length (cm) of fish, ' a '=intercept, and ' b '=slope (regression coefficient which lies between 2 and 4; while isometric (symmetric) growth is indicated at 3, and values other than 3 will indicate allometric growth, i.e. values greater than 3=positive allometric growth, and values less than 3=negative allometric growth).

Linear regression of graph of length–weight relationship of fish species were plotted.

The condition factor

The condition factor of fish samples collected were determined using the formular (Pauly, 1983):

$$K = 100W/L^b.$$

where K =condition, W =Weight (g), L =Length (cm), b =isometric value.

Heavy metal analysis

The fish samples collected from Asejire reservoir and Lagos Lagoon were subjected to heavy metal assessments according to Association of Official Analytical chemists (2007), US-FDA (1993), EC (1998), EPA (2002), WHO (2003), WPCL (2004) and SON (2007) protocols on heavy metals hazard control points as guild on required permissible level/limit. Lead (Pb), chromium (Cr), iron (Fe), zinc (Zn), and copper (Cu) were estimated using electro photometer, (Buck 211 model). Samples were digested

and the following steps were taken during the digestion of the fish species:

Fish samples collected and oven-dried were weighed into crucible and heated in muffle furnace for two hours at 750 °C temperature. 5 g of powdered samples were weighed into 100 ml beaker. 15ml freshly prepared mixture of $\text{HNO}_3/\text{H}_2\text{O}_2$ ratio 1:1 ratio was added to each sample and covered with wash glass and allowed to stand for 30 min during which initial reaction subsided. Digestion processes were carried out on hot plate with gradual increase in temperature rise to a maximum temperature of 160 °C in a fume cupboard with heat for 2 h, to evaporate/reduce volume in the beaker to 5 ml. Beaker and contents were air cooled and content transferred with Whatman filtration into 50ml volumetric flask and made up to mark with distilled water. Digested samples were analyzed for Pb, Fe, Zn, Cu and Cr using buck 211 model atomic absorption spectrophotometer with aqueous calibration standard prepared from the stock standard solutions of the respective elements.

Statistical Analysis: Analytical and descriptive statistics were used to analyse data collected; two-way ANOVA was used to determine interaction within location; and standard deviation of means and standard errors were calculated using Statistical Package for Social Sciences (SPSS) 18 edition.

(i.) regression analysis was used to determine sequence of length and weight of fish; while Duncan Multiple Range Test (DMRT) was carried out to determine level of significance among fish samples;

(ii.) Duncan Multiple Range Test (DMRT) was used to determine significance relationship of heavy metals concentration determined in *O. niloticus* and *C. nigrodigitatus* between and within Asejire reservoir and Lagos Lagoon.

Result

A total of seventy-two samples of *O. niloticus* and *C. nigrodigitatus* were collected respectively from Asejire Reservoir and Lagos Lagoon. *C. nigrodigitatus* collected from both locations revealed no significant difference ($P < 0.05$) in Length. Weight (196.06 ± 0.16 g) recorded in Lagos Lagoon *C. nigrodigitatus* sample was significantly different ($P < 0.05$) from Asejire Reservoir *C. nigrodigitatus*. There was no significant different ($P > 0.05$) in weight between *O. niloticus* specie from the two locations.

Highest condition factor (4.56) was recorded in Asejire Reservoir *O. niloticus* and lowest condition factor (1.64) was determined in Asejire Reservoir *C. nigrodigitatus*. The least isometric value (1.40) was recorded in Lagos Lagoon *C. nigrodigitatus*, and this indicated a negative allometric value.

The frequency and growth determination of the two species within and between locations

Frequency and growth in *Oreochromis niloticus* and *Chrysichthys nigrodigitatus* collected from Asejire Reservoir and Lagos Lagoon; and frequency and growth trend in male and female *O. niloticus* and *C. nigrodigitatus* are indicated in Table 1. Samples from the seventy—two *C. nigrodigitatus* and *O. niloticus* collected from both species and locations respectively showed Lagos Lagoon Male *C. nigrodigitatus* had highest frequency (40) among the fish species from the two locations. No significant different ($P>0.05$) occurred in length and weight within species and between locations for *O. niloticus* fish; there was significant different ($P<0.5$) between locations, but not within species for *C. nigrodigitatus* length and weight measurements.

C. nigrodigitatus fish indicated a negative allometric value within and between locations and, but positive allometric in male Lagos Lagoon *C. nigrodigitatus* samples. Highest value was determined in male

O. niloticus from Asejire Reservoir. The condition factor determined revealed male *O. niloticus* from Lagos Lagoon had highest value between locations for *O. niloticus* specie, and recorded highest value within specie, between locations. Among fish samples, female *C. nigrodigitatus* recorded least condition factor (K), which may be reproductive, environmental and / or food availability linked.

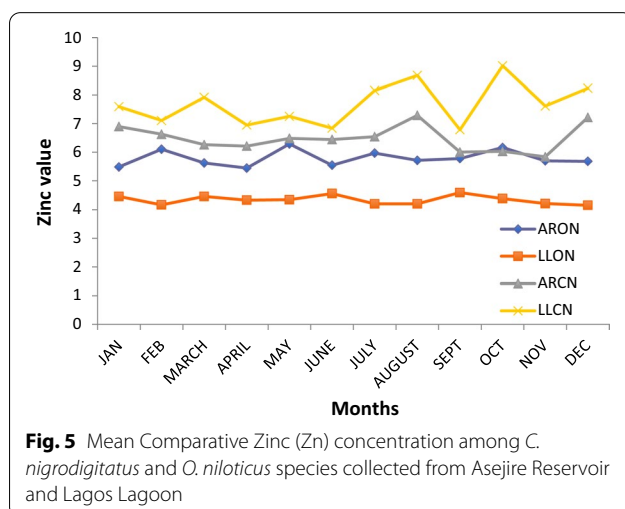
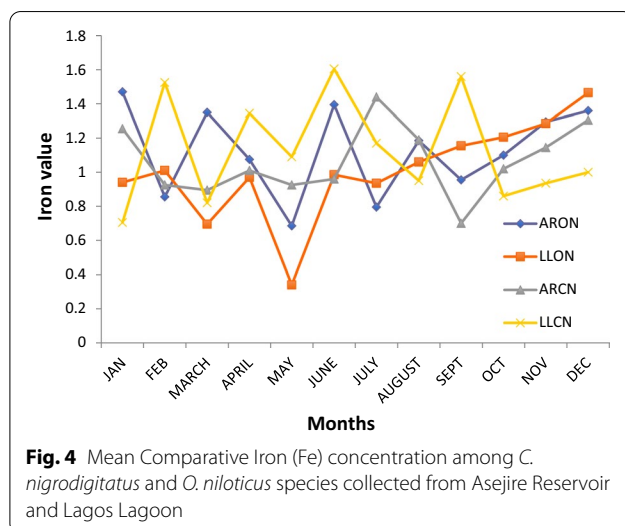
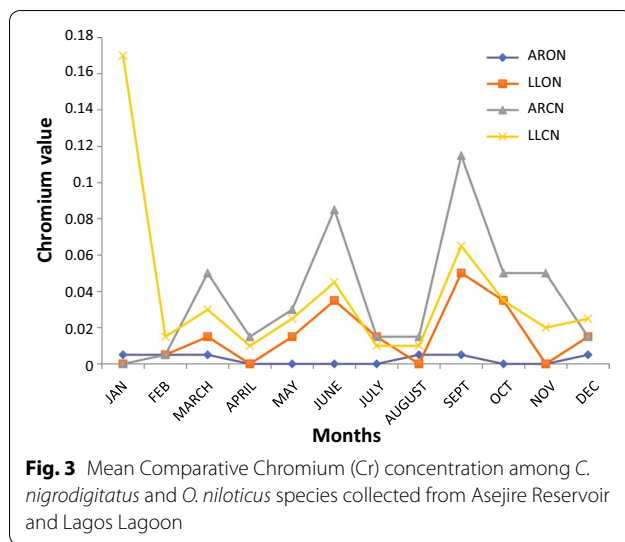
Heavy metals in *Chrysichthys nigrodigitatus* and *Oreochromis niloticus*

Heavy metals determined in homogenized *C. nigrodigitatus* and *Oreochromis niloticus* collected from Lagos Lagoon and Asejire Reservoir are indicated below. Figures 3, 4, 5, 6 and 7 shows the mean comparative heavy metals determination in the fish samples between locations; and Figs. 8, 9, 10 and 11 revealed seasonal heavy metals determinations.

Table 1 Sex frequency and length–weight indices on *O. niloticus* and *C. nigrodigitatus* from Asejire Reservoir and Lagos Lagoon

Locations	Fish spp.	Frequency	Mean standard length (cm) ± Standard deviation	Mean weight (g) ± Standard deviation	Coefficient (b-value)	Condition factor (K-factor)	Regression equation	Regression (R^2)	Regression (r-value)
Asejire Reservoir	<i>O. niloticus</i>	72	12.52 ± 0.03 ^b	78.59 ± 0.12 ^c	3.05 ^a	4.56 ^a	$y = 3.0507x - 3.6878$	0.85 ^a	0.92 ^a
Lagos Lagoon	<i>O. niloticus</i>	72	13.09 ± 0.03 ^b	78.87 ± 0.10 ^c	2.72 ^b	4.26 ^b	$y = 2.7189x - 2.8897$	0.72 ^b	0.85 ^b
Asejire Reservoir	<i>C. nigrodigitatus</i>	72	20.02 ± 0.05 ^a	111.55 ± 0.14 ^b	1.98 ^c	1.64 ^d	$y = 1.9848x - 1.3809$	0.61 ^c	0.78 ^c
Lagos Lagoon	<i>C. nigrodigitatus</i>	72	22.68 ± 0.03 ^a	196.06 ± 0.16 ^a	1.40 ^c	2.43 ^c	$y = 1.398x + 0.6536$	0.58 ^d	0.76 ^c
Asejire Reservoir Male	<i>O. niloticus</i>	34	13.10 ± 0.06 ^c	95.38 ± 0.38 ^b	3.06 ^a	2.52 ^c	$y = 3.0648x - 3.8209$	0.80 ^a	0.89 ^a
Asejire Reservoir Female	<i>O. niloticus</i>	38	13.15 ± 0.05 ^c	62.32 ± 0.21 ^c	2.23 ^c	1.54 ^d	$y = 2.2248x - 1.539$	0.63 ^c	0.79 ^b
Lagos Lagoon Male	<i>O. niloticus</i>	42	12.63 ± 0.05 ^c	78.53 ± 0.19 ^c	2.70 ^b	4.75 ^a	$y = 2.7036x - 2.7772$	0.80 ^b	0.92 ^a
Lagos Lagoon Female	<i>O. niloticus</i>	30	13.67 ± 0.06 ^c	79.29 ± 0.19 ^c	2.99 ^a	3.89 ^b	$y = 2.9921x - 3.7117$	0.64 ^c	0.80 ^b
Asejire Reservoir Male	<i>C. nigrodigitatus</i>	38	20.10 ± 0.09 ^b	108.08 ± 0.26 ^b	2.30 ^c	1.54 ^d	$y = 2.3046x - 2.3014$	0.62 ^c	0.79 ^{bc}
Asejire Reservoir Female	<i>C. nigrodigitatus</i>	34	19.93 ± 0.11 ^b	115.89 ± 0.33 ^b	1.88 ^d	1.75 ^{cd}	$y = 1.8757x - 0.9265$	0.70 ^b	0.83 ^b
Lagos Lagoon Male	<i>C. nigrodigitatus</i>	40	22.56 ± 0.05 ^a	207.76 ± 0.29 ^a	1.22 ^d	3.26 ^{bc}	$y = 1.2214x + 1.2741$	0.57 ^c	0.76 ^c
Lagos Lagoon Female	<i>C. nigrodigitatus</i>	32	22.85 ± 0.07 ^a	180.46 ± 0.36 ^a	2.63 ^b	1.43 ^d	$y = 2.632x - 3.1997$	0.61 ^c	0.78 ^c

Means with the same superscripts along the column are not significantly different, ($P>0.05$)



Heavy metals in *Oreochromis niloticus*

The values of Heavy metals determined on *O. niloticus* flesh collected from Lagos Lagoon indicated that Iron (Fe) ranged between 0.34 ± 0.09 ppm and 1.46 ± 0.48 ppm, while that of chromium (Cr) ranged between 0.01 ± 0.00 ppm and 0.03 ± 0.00 ppm. For zinc (Zn), this ranged from 3.39 ± 0.36 ppm and 4.71 ± 0.25 ppm. Values obtained in Copper (Cu) ranged between 0.49 ± 0.10 ppm and 0.86 ± 0.07 ppm; and that of Lead (Pb) was 0.01 ± 0.00 ppm and; while 71.43% of samples had no Lead (Pb) determination.

Heavy metals determined on *O. niloticus* flesh collected from Asejire reservoir indicated values obtained in Iron (Fe) range between 0.45 ± 0.11 ppm and 1.84 ± 0.45 ppm. Value obtained for chromium (Cr) was 0.01 ± 0.00 ppm, in 57.14% of samples, and 42.86% had no determination. Values obtained in zinc (Zn) ranged from 5.20 ± 0.62 ppm and 6.52 ± 0.82 ppm. Values obtained in Copper (Cu): ranged between 0.60 ± 0.04 ppm and 0.70 ± 0.12 ppm.

Heavy metals in *Chrysichthys nigrodigitatus*

Heavy metals determined on *C. nigrodigitatus* flesh collected from Lagos Lagoon indicated values obtained in Iron (Fe) range between 0.59 ± 0.03 ppm and 2.02 ± 0.64 ppm. Value obtained for chromium (Cr) range between 0.01 ± 0.00 ppm and 0.06 ± 0.01 ppm. Values obtained in zinc (Zn) ranged from 5.83 ± 0.66 ppm and 9.56 ± 0.96 ppm. Values obtained in Copper (Cu): ranged between 0.43 ± 0.08 ppm and 3.69 ± 5.66 ppm. Value obtained in Lead (Pb) ranged between 0.13 ± 0.06 ppm and 0.20 ± 3.40 ppm.

Heavy metals assessment on *C. nigrodigitatus* flesh collected from Lagos Lagoon indicated values obtained in Iron (Fe) range between 0.59 ± 0.03 ppm and 2.02 ± 0.64 ppm. Value obtained for chromium (Cr) range between 0.01 ± 0.00 ppm and 0.06 ± 0.01 ppm. Values obtained in zinc (Zn) ranged from 5.83 ± 0.66 ppm and 9.56 ± 0.96 ppm. Values obtained in Copper (Cu): ranged between 0.43 ± 0.08 ppm and 2.69 ± 1.66 ppm. Value obtained in Lead (Pb) ranged between 0.13 ± 0.06 ppm and 0.20 ± 0.04 ppm.

Heavy metals maximum and minimum concentrations in samples of *C. nigrodigitatus* and *O. niloticus* in Lagos Lagoon and Asejire Reservoir respectively is revealed in Table 2.

Result above indicated *Chrysichthys nigrodigitatus* catfish accumulate heavy metals more than *Oreochromis niloticus* tilapia fish. Also, samples from Lagos Lagoon accumulate more heavy metals than samples from Asejire Reservoir.

The significance level of heavy metals in species and locations indicated was assessed with probability at

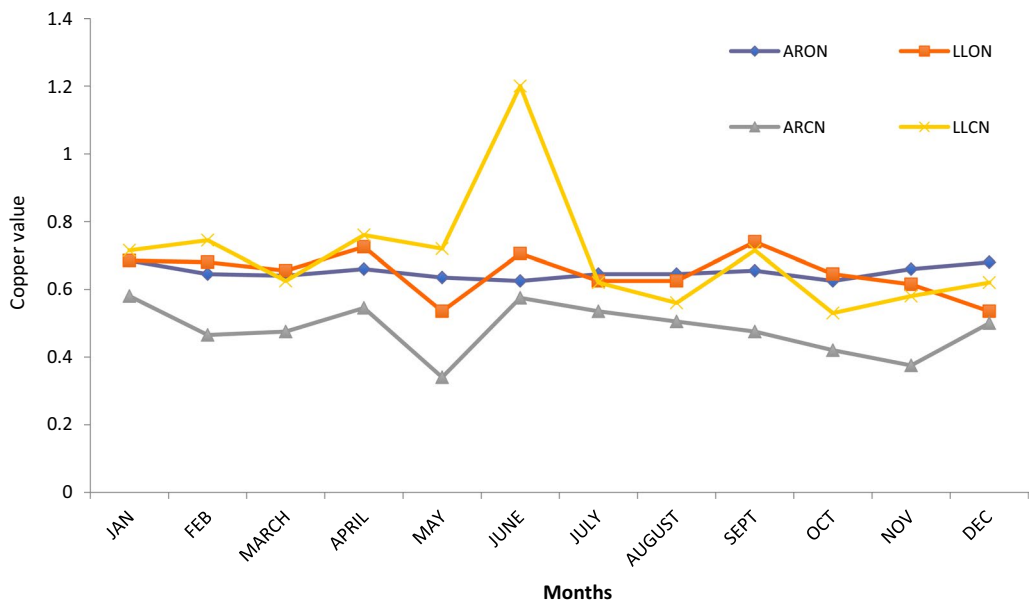


Fig. 6 Mean Comparative Copper (Cu) concentration among *C. nigrodigitatus* and *O. niloticus* species collected from Asejire Reservoir and Lagos Lagoon

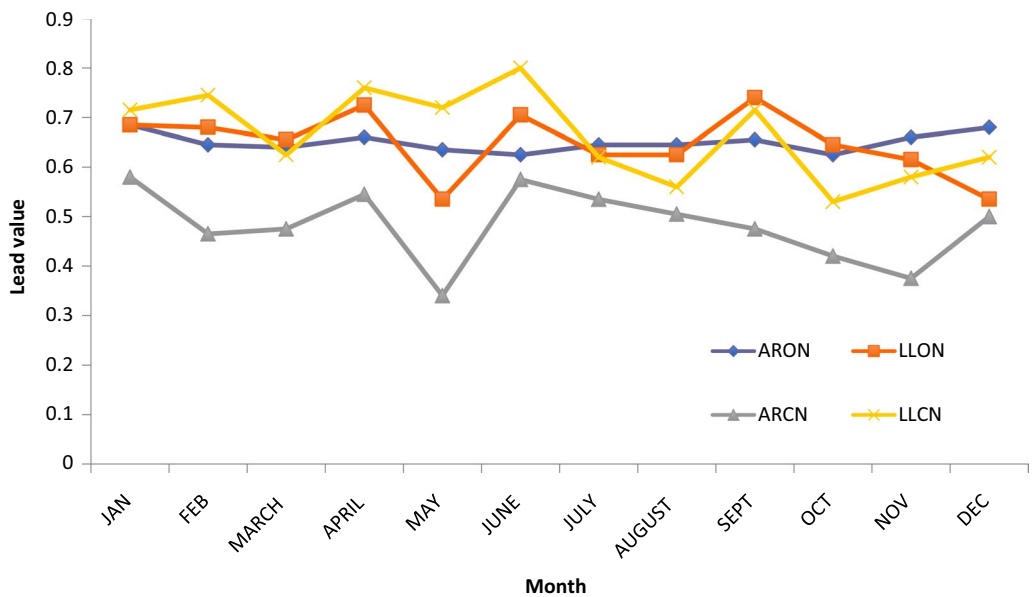


Fig. 7 Mean Comparative Lead (Pb) concentration among *C. nigrodigitatus* and *O. niloticus* species collected from Asejire Reservoir and Lagos Lagoon

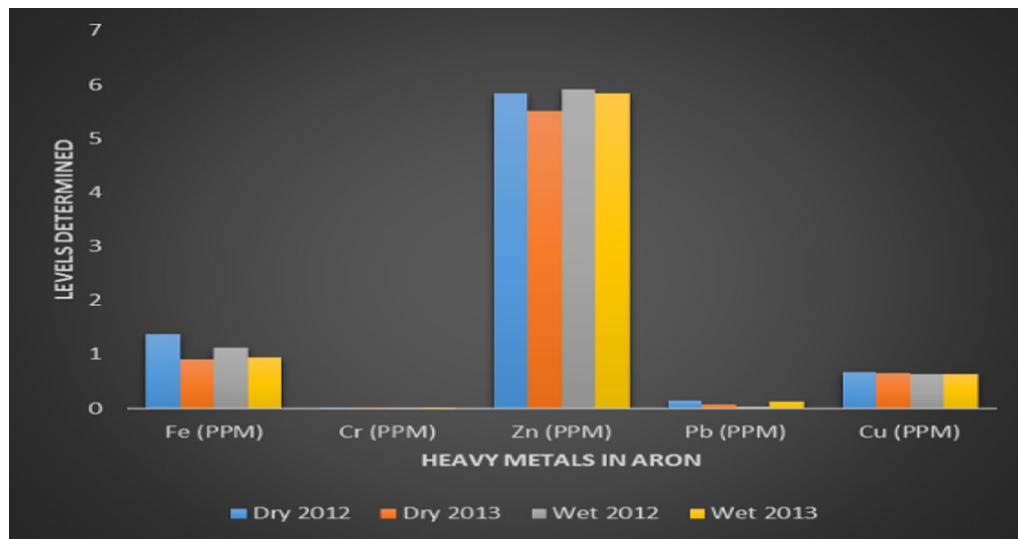


Fig. 8 Seasonal variations in heavy metals in *O. niloticus* collected from Asejire Reservoir

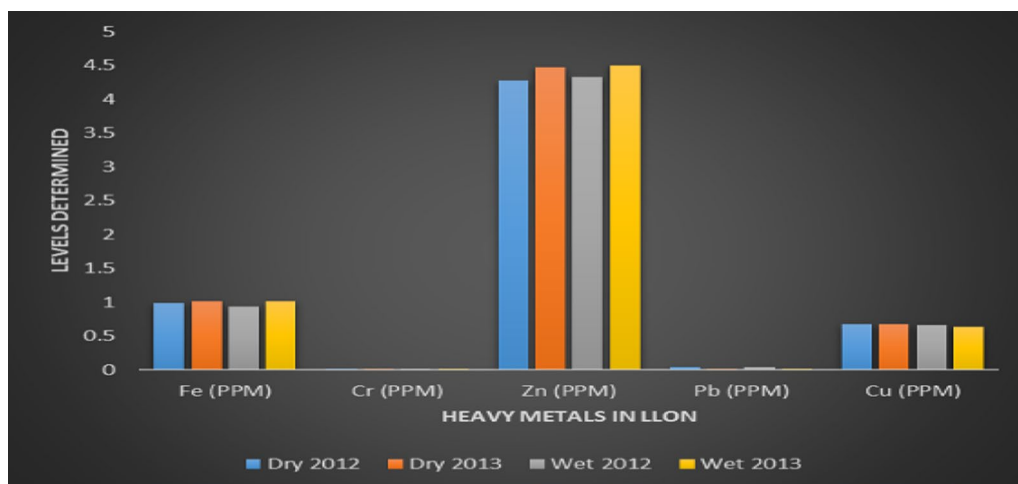


Fig. 9 Seasonal variations in heavy metals in *O. niloticus* collected from Lagos Lagoon

$P > 0.05$ non-significant level and $P < 0.05$ significant level. Result obtained indicated:

- Fe has no significant difference between species *C. nigrodigitatus* and *O. niloticus* btw Lagos Lagoon and Asejire Reservoir between locations
- Cr has significant difference among species *C. nigrodigitatus* and *O. niloticus* in Lagos Lagoon; and no significant difference in *C. nigrodigitatus* and *O. niloticus* in Asejire Reservoir
- Zn has significant difference between *C. nigrodigitatus* and *O. niloticus* in Lagos Lagoon and Asejire Reservoir; but no significant difference within species *C.*

nigrodigitatus and *O. niloticus* respectively between Lagos Lagoon and Asejire Reservoir locations

- Cu has significant difference between Lagos Lagoon and Asejire Reservoir locations and *C. nigrodigitatus* and *O. niloticus* species; and no significant difference within location and *C. nigrodigitatus* and *O. niloticus* species.
- Pb has no significant difference between locations Lagos Lagoon and Asejire Reservoir and species *C. nigrodigitatus* and *O. niloticus*.

Significant difference ($P < 0.05$) occurred among samples, as it was higher in dry season than rainy season.

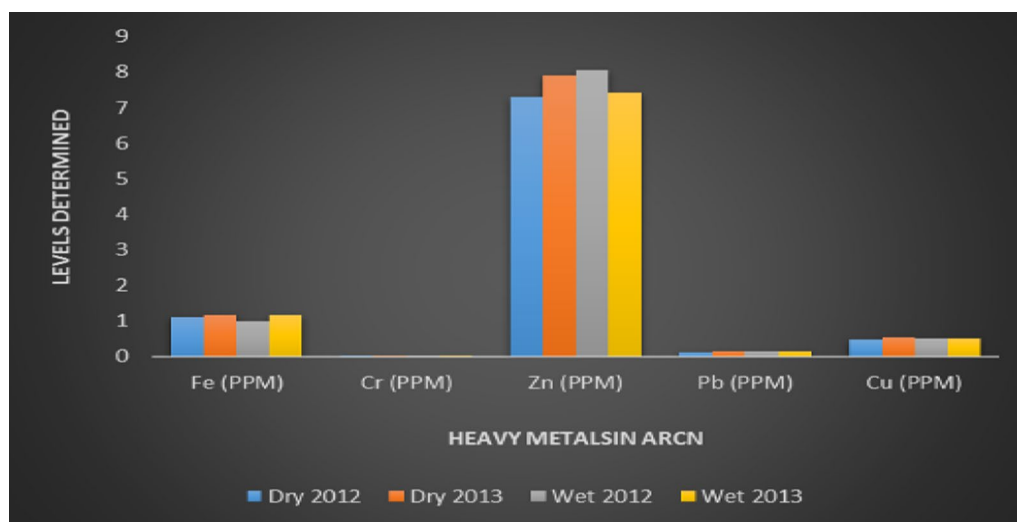


Fig. 10 Seasonal variations in heavy metals in *C. nigrodigitatus* collected from Asejire Reservoir

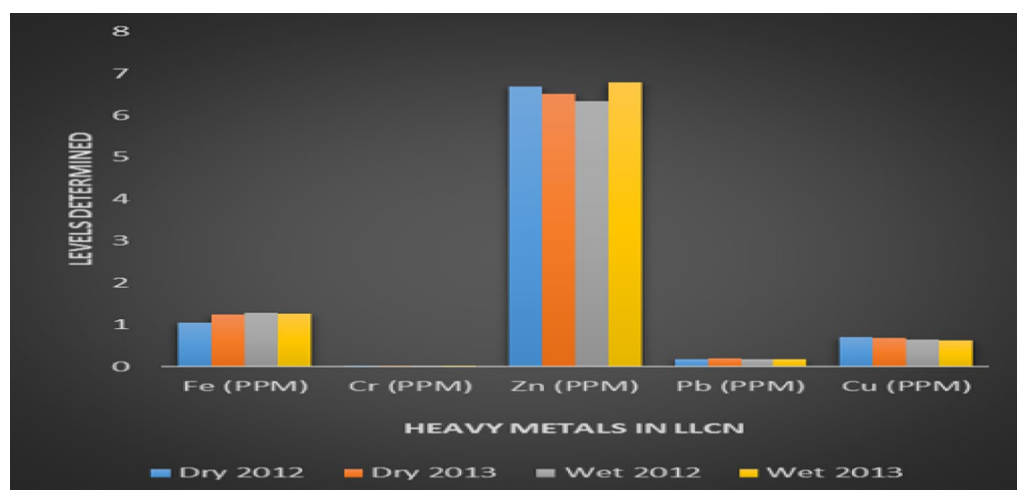


Fig. 11 Seasonal variations in heavy metals in *C. nigrodigitatus* collected from Lagos Lagoon

Table 2 Maximum and Minimum Heavy Metals Concentration in *Chrysichthys nigrodigitatus* and *Oreochromis niloticus*

Heavy Metal	Max. mean (mg g ⁻¹)	Fish spp. by location	Mini. mean (mg g ⁻¹)	Fish spp. By location	Recommended limits in fish
Fe	2.02 ± 0.64	LLCN	0.34 ± 0.09	ONLL	146.00 mg (IAEA-407; Wyse et al., 2003)
Cr	0.08 ± 0.00	ARC�	0.05 ± 0.00	ARON	(0.020 mg/g) (WPCL, 2004)
Zn	9.56 ± 0.96	LLCN	3.93 ± 0.36	LLON	3.00 mg g ⁻¹ (WHO, 2003)
Pb	0.27 ± 0.12	ARC�	0.1 ± 0.00	LLON	0.12 mg g ⁻¹ (IAEA-407; Wyse et al., 2003)
Cu	0.89 ± 0.23	LLCN	0.30 ± 0.13	ARC�	3.28 mg g ⁻¹ (IAEA-407; Wyse et al., 2003) 0.03 mg g ⁻¹ (Khayazadeh and Abbasi, 2010)

LLCN (Lagos Lagoon *Chrysichthys nigrodigitatus*); ARC� (Asejire Reservoir *Chrysichthys nigrodigitatus*); LLON (Lagos Lagoon *Oreochromis niloticus*); ARON (Asejire Reservoir *Oreochromis niloticus*);

Discussion

Sex differences of *O. niloticus* collected indicated no significant difference in length of fish between and within locations and in both sexes (male and female); while significant differences were revealed in weight. Significant differences were revealed in weight of fish samples collected from Asejire reservoir and Lagos Lagoon revealed no significant difference.

Assessment of length and weight of *C. nigrodigitatus* and *O. niloticus* from Asejire Reservoir and Lagos Lagoon revealed no significant difference in length of fish species sampled, but significant difference occurred in weight within specie; with respect to locations respectively for *O. niloticus*; but for *C. nigrodigitatus*, significant difference occurred in weight of fish samples collected between locations and not within locations. This inference is sequential to ecological condition influences as well as environmental functioning entities within the water bodies; as growth among specie is in normal sequence as determined by genes and environmental factors to give required fish size (Guillaume et al., 2007).

Condition factor (K) parameters by species, by locations, within species and among species indicated that *C. nigrodigitatus* in Asejire Reservoir and Lagos Lagoon had K factor. Highest K-factor was revealed in male Lagos Lagoon *O. niloticus* among species and between sexes, while female Lagos Lagoon *C. nigrodigitatus* had lowest K-factor (1.43). This could be attributed to reproduction. Within species, between locations and within sex, female *O. niloticus* from Lagos Lagoon had higher condition factor than the female from Asejire Reservoir. Among the male sex, *O. niloticus* from Lagos Lagoon perform better than Asejire Reservoir Male *O. niloticus*. Male *C. nigrodigitatus* from Lagos Lagoon had higher condition factor than the male *C. nigrodigitatus* in Asejire Reservoir, while female *C. nigrodigitatus* from Asejire Reservoir had higher K-factor than female *C. nigrodigitatus* in Lagos Lagoon. it is indicative of the nature of the fish which that it increases largely more in weight than in length; and the result is in line with the findings of Froese (2006) who stated that condition factor (K) of fish can be species specific, reproductive, sex specific, location specific, and feeding specific (Froese, 2006; George et al., 2013).

Mean parameter b values obtained within location and between locations Asejire Reservoir and Lagos Lagoon indicated that *O. niloticus* from Asejire Reservoir had highest b-value which is positive allometric, and between locations among species, *O. niloticus* had highest b-values, revealing a positive allometric, which indicated the level of robustness of the fish. Male *O. niloticus* from Asejire Reservoir had highest b-value

among species between locations, which is positive allometric and the least of the b-value was recorded in *C. nigrodigitatus* from Lagos Lagoon, and this indicated a negative allometric b-values which indicated that the fish increase more in length than in weight as this is supportive of the nature of the fish and in line with the work of Froese (2006).

Assessment of Iron (Fe), chromium (Cr), zinc (Zn), copper (Cu), lead (Pb) were carried out on *Chrysichthys nigrodigitatus* and *Oreochromis niloticus* from Asejire Reservoir and Lagos Lagoon; and results obtained revealed presence of heavy metals in fish species collected from both locations. Therefore, assessment of health status and health implication of heavy metal for fish eco-monitoring and public health cannot be overly emphasized.

Concentration of Fe in flesh of *O. niloticus* and *C. nigrodigitatus* within and between locations revealed a higher value from concentration limit (0.300 mg/g) (SON, 2007; WPCL, 2004) and (0.500 mg/g). Concentration of Fe (2.02 mg/g) was highest in *C. nigrodigitatus* from Lagos Lagoon, but lower than concentration level (3.58 mg/g) obtained by Coale (1991). While Fe is essential to most life forms and to normal human physiology, as it is essential in oxygen transports from lungs to tissues (Dallman, 2006); it is also essential for the regulation of cell growth and differentiation. Present for production of hemoglobin, myoglobin; and its deficiency can cause anemia, (Anderson et al., 2010). According to Davis et al. (2008) reported that excess Fe in biological tissues causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness; this is implicative on state of well-being and hematology of fish to stress conditions.

Concentration of zinc (Zn) in flesh of *O. niloticus* and *C. nigrodigitatus* within and between locations revealed higher value in species within and between locations, except in *O. niloticus* from Lagos Lagoon (4.71 mg/g) which fell slightly below permissible limit (5.000 mg/g) (Opaluwa et al., 2012), but above permissible limits (0.1 mg/g); (3.000 mg/g) (SON, 2007; WHO, 2003); and (4.250 mg/g). Highest concentration (9.56 mg/g) was revealed in *C. nigrodigitatus* from Lagos Lagoon which was higher than concentration (0.08 mg/g) obtained in Lagos Lagoon. Differences in concentrations could be or are linked with location, specie(s), age and size specific as observed in the results of the study (Peakall & Burger, 2003). Zinc may induce toxicity, characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite, and nausea (Sharma et al., 2014). Singh et al. (2011) reported that water hardness and pH can intensify toxicity of Zn. Hence, results indicated ecosystem challenge as well as public health attention on

consumers long run consumption and accumulations (Singh et al., 2011).

Concentration of copper (Cu) in the flesh of *C. nigrodigitatus* and *O. niloticus* within and between location indicated that values obtained were higher than the recommended limit (0.03 mg/g) (Fafioye et al., 2017) and higher than value obtained in Lagos Lagoon (0.52 mg/g). Highest value obtained in *C. nigrodigitatus* from Lagos Lagoon and lowest value obtained in *C. nigrodigitatus* collected from Asejire reservoir is indicative of size, specie tolerance/ immunity, and location specific (water parameter) which is affect the condition factor of the fish. And may lead to retarded growth and inhibition of spawning. High concentration of copper can alter haematology (James et al., 2008) respiratory and cardiac physiology (Tchounwou et al., 2012).

Concentration of lead (Pb) in the flesh of *C. nigrodigitatus* and *O. niloticus* within and between locations indicated that values obtained had no significant difference between locations and species and within locations. Values obtained are relative to recommended limits (0.010 mg/g) (SON, 2007; WPCL, 2004; EPA, 2002). The result revealed higher deviation from recommended limit (0.0005–0.0006 mg/g); while Pb in *C. nigrodigitatus* collected from Asejire reservoir had highest value, and *O. niloticus* from Lagos Lagoon had the least. Water quality and rate at which lead dissolves contributes to its concentration in the environment. Pb causes lamella shrinkage degeneracy of epithelium, ischemia, reduction in growth rate, branchial arterial rupture. Loss in body weight, neurological defect, renal tubular dysfunction, anemia which results in stress condition are other defects of high concentration of Pb (Tchounwou et al., 2012). Concentration of chromium (Cr) in the flesh of *C. nigrodigitatus* and *O. niloticus* within and between locations indicated that, *O. niloticus* from Lagos Lagoon had higher value than recommended limits (0.013 mg/g) (US-FDA, 1993); (0.020 mg/g) (WPCL, 2004); values obtained in *O. niloticus* species between locations fell below recommended limit (0.050 mg/g) (SON, 2007; EPA, 2002; EC, 1998). Values for *C. nigrodigitatus* exceeded the recommended limits; as specie specificity is indicated. Chromium (Cr) deficiency results in impaired growth and disturbances in glucose, lipid and protein metabolism; while excess could have undesirable lethal effect on fish and wildlife (Barr, 2018) oxidizes easily from trivalent to hexavalent. Cr ion and is not toxic, but an essential nutrient, but Cr ion is very toxic and damages adrenals, livers and lungs. Exposure of man to high concentration of Cr may cause dermatitis, ulcer, destruction of mucus of nose and cancer of the stomachs. The major source of Cr in water is via industrial effluents.

The study revealed that, there is significant difference in the level of heavy metal determined ($P < 0.05$). Seasonal impact and rainfall had influence in the level of heavy metals in the fish flesh and these were in the order: $Zn > Fe > Cu > Pb > Cr$: $(6.52 \pm 0.82 > 1.84 \pm 0.45 > 0.70 \pm 0.12 > 0.20 \pm 0.00 > 0.01 \pm 0.00)$ for *O. niloticus* in Asejire reservoir. In Lagos Lagoon, metal order for *O. niloticus* flesh was ranked: $Zn > Fe > Cu > Cr > Pb$ $(4.71 \pm 0.25 > 1.46 \pm 0.48 > 0.86 \pm 0.07 > 0.03 \pm 0.00 > 0.01 \pm 0.00)$ Lagos Lagoon *C. nigrodigitatus* metal level were ranked: $Zn > Cu > Fe > Pb > Cr$: $(9.56 \pm 0.96 > 3.69 \pm 1.66 > 2.02 \pm 0.64 > 0.20 \pm 0.34 > 0.06 \pm 0.01)$; and Asejire Reservoir *C. nigrodigitatus* metal level were ranked: $Zn > Cu > Fe > Pb > Cr$ $(9.56 \pm)$ In all, Zinc (Zn) dominates and top ranked in level among species and between locations indicating stress induced environments.

Conclusion

Samples of fish collected revealed a sequence within normal range of male to female sex ratio; but the variation recorded in size is indicative of environmental influences such as biotic and abiotic factors. Higher condition factor recorded in male fish is indicative of gender differences; and higher length and weight in Lagos Lagoon fish species are indicative of an ecotone environment, rich and receiving input from fresh and marine environments.

Ecosystem status indicated determined heavy metals stressors being location specific, and create public health alert for accumulation and effect on consumers. Hence, stressors synergizing situation exposed fish to high risk health status, which will resultantly become of public concern to man; as such fish may pose as food poisoning.

Abbreviations

AOAC: Association of Official Analytical Chemists; ARCN: Asejire Reservoir *Chrysichthys nigrodigitatus*; ARON: Asejire Reservoir *Oreochromis niloticus*; LLCN: Lagos Lagoon *Chrysichthys nigrodigitatus*; LLON: Lagos Lagoon *Oreochromis niloticus*; Pb: Lead; Cr: Chromium; Zn: Zinc; Fe: Iron; Cu: Copper; ANOVA: Analysis of Variance; SON: Standard Organization of Nigeria; US-FDA: United State—Food and Drug Agency; WPCL: Water Pollution Control Legislation; EPA: Environmental Protection Agency; FEPA: Federal Environmental Protection Agency; EC: European Commission; NIOMR: Nigerian Institute for Oceanography and Marine Research; K: Condition factor; WHO: World Health Organization; UNEP: United Nations Environment Programme.

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Authors' contributions

This research work, design and analysis were carried out by all the authors. The manuscript was put together by AOA. All authors read and approved the final manuscript.

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Declarations**Ethics approval and consent to participate**

The research involves collection of samples from animal (fish) subjects. Community representatives were contacted in the selected environments for permission to carry out the field assessments and research work. Guidelines according to Nickum et al. (2004) were followed in collection of fish samples. Heavy metal analysis regulation was done according to AOAC (2007) and EPA (2015).

Consent for publication

Not applicable.

Competing interests

The authors declare that there is no competing interest.

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