Studies on heavy metals and fish health indicators in *Malapterurus electricus* from Lekki Lagoon, Lagos, Nigeria

Minasu P. Kuton [a], Isaac O. Ayanda [b,*], Ijeoma A. Uzoalu [a], Dorathy I Akhiromen [a], Aderonke George [a], Bamidele Akinsanya [c]

[a] *Department of Marine Sciences, University of Lagos, Akoka, Lagos State, Nigeria*
[b] *Department of Biological Sciences, Covenant University, Ota, Ogun State, Nigeria*
[c] *Department of Zoology, University of Lagos, Akoka, Lagos State, Nigeria*

ARTICLE INFO

ABSTRACT

The aquatic ecosystem is constantly being disturbed by rising levels of different classes of pollutants of human origin in the form of urban, agricultural and industrial discharges. In this study, the health of fish *Malapterurus electricus* was examined, to serve as a reflection of the impact of anthropogenic disturbances in the Lekki lagoon. Eighty six samples of the fish were analysed for parasitic infections, heavy metals, microorganisms in their internal and external body parts while the proximate composition and fish condition factor were also determined using conventional methods. One parasite species, a cestode *Electrotaenia malapteruri* was found to infect the fish. Total parasite load was eighty five with a total prevalence of infection of 36%. Elements detected in sediment were of the order of Al>Fe>Mn>Pb>Cr>Zn>Cd>Ba>Cu>Ni while in water, it is Mn>Fe>Zn>Ba>Cd>Cr>Al>Cu>Ni>Pb. Metals analysed in the fish tissues were generally low and below regulatory limits. In the proximate analysis, moisture content has a value of 80.7%, while ash content had a value of 1.26%. Eight bacterial and two fungal species were isolated from the fish. The condition factor of fish varied between 1 and 2. The study provides valuable information for monitoring and management of heavy metal pollution in the aquatic ecosystem.

1. Introduction

The contribution of fish to animal proteins cannot be overestimated (Abolagba & Melle, 2008). It is low in cholesterol and contains the essential amino acids. It has been estimated that the contribution of fish to the global demand for protein is about 60% and that 60% of the developing world derives more than 30% of their animal protein from fish (Emikpe, Adebisi, & Adedeji, 2011). Unfortunately, lately, the habitat of fish, the aquatic ecosystem have been seriously threatened by all forms of human activities (Meijide et al., 2018; Zhu, Zhang & Zagar, 2018). A large amount of chemicals is being constantly discharged into the aquatic environment and these persist in biota, water and sediment. Chemicals of organic and inorganic sources are a major contributor to poisoning of natural waters (Van der Oost, Beyer & Vermeulen, 2012), consequently affecting the aquatic biota (Schmeller et al., 2018).

Metals such as cadmium, mercury, lead and arsenic are non-essential metals and are referred to as highly toxic as they are harmful at low concentrations. These toxic chemical elements are the prominent inorganic contaminants (Gupta, Khan & Santra, 2012). Heavy metals toxicity has proved to be a major threat as several health risk are associated with them (Shah, 2017). Environmental contamination and organisms' exposure to these toxic metals results majorly from anthropogenic activities such as domestic and agricultural use of chemical metals by pesticides and fertilizer application, emissions from municipal or local wastes, emission from incinerators, mining and smelting operations etc. (Singh, Sharma, Agrawal, & Marshall, 2010).

Parasites constitute a serious limiting factor to the growth of fish in Nigeria (Bichi & Yelwa, 2010). They affect fish in the following way - nutrient devaluation (Hassan, Akinsanya, Adegbaju, & , 2010), alteration of behavior and biology (Lafferty, 2008), reduction of immune capacity, morbidity and even mortality (Nmor et al., 2004). Often times, they also cause mechanical injuries depending on the parasitic species and abundance (Echi et al., 2009).

Microbial colonization is relevant in aquaculture; while some occur naturally, they can be added to meet various requirements. Microorganisms recycle nutrient, degrade organic matter and, in some cases,

infect and kill fish, their larvae or feed (Bentzon-Tilia et al., 2015). Hence, it is of great necessity that the microbial communities be monitored as this would aid the assessment and improvement of water quality as well as controlling the prevalence of microbial infections.

The African electric catfishes are prevalent to tropical Africa (Leveque, Paugy & Teugels, 1991), and of the three species currently recognized (*M. electricus, M. minjiriya, M. microstoma*) (Teugels, 1996), *M. electricus* enjoys a frequent catch for commercial purposes in Western Africa (Holden & Reed, 1972). The electric organ has the capacity to generate 300–400 Vs, forms a covering underneath the skin surrounding the body, and this is used for capture of prey and protection (Skelton, 1993). They are highly relished as food among consumers, especially when smoked. Usually, either smoked or fresh, the thick unpalatable skin must be removed in order to enjoy the tasty flesh.

The Lekki lagoon in Lagos, has become a dumping site for industrial wastes from industries in the state leading to heavy contamination of the lagoon. Thus, so that normal functioning of the ecosystem may not be hampered, and to ensure the protection of aquatic biota, it is crucial to study the activities that pollute the aquatic environment including their spatial distribution (Liu, Lu, Guo, Xi & Wang, 2018; Zhao et al., 2018). In this study, samples of electric fish were collected from the Lekki Lagoon and they were characterized for presence of heavy metals, examined for parasitic and microbial infection and analysed for proximate composition to serve as a reflection of the health status of fish species in the lagoon.

2. Materials and methods

2.1. Study area

The Lekki lagoon, located in South-Western Nigeria, Lagos State lies between latitude 06°3035.57″N and longitudes 4°757.58″E (Fig 1). The lagoon lies within the rainforest belt of southern Nigeria, experiencing two major seasons. Riparian vegetation at the bank of the lagoon consists mainly of grasses and secondary rainforest. Agriculture, sand mining, artisanal fisheries and transportation of people and goods using motorized boats are some of the human activities that goes on in the study stretch. Various kinds of wastes are constantly being dumped into the lagoon. In addition, most inhabitants of the shore communities do not have toilet facilities hence, defecation and release of other human wastes into the lagoon are common features in the area.

2.2. Collection of fish samples

A total of eighty-six (86) life fish specimens of *Malapterurus electricus* were freshly obtained from the study area during a period of July to November 2019 at five sampling points in the lagoon namely – Ajegunle (20), Luboye (18), Origbe (15), Iwopin (14) and Aba Ereke (19). The sample size is based on catch by the fishermen. The fishes were purchased at the landing sites of fishermen in Olowo fish market, Epe, Lagos
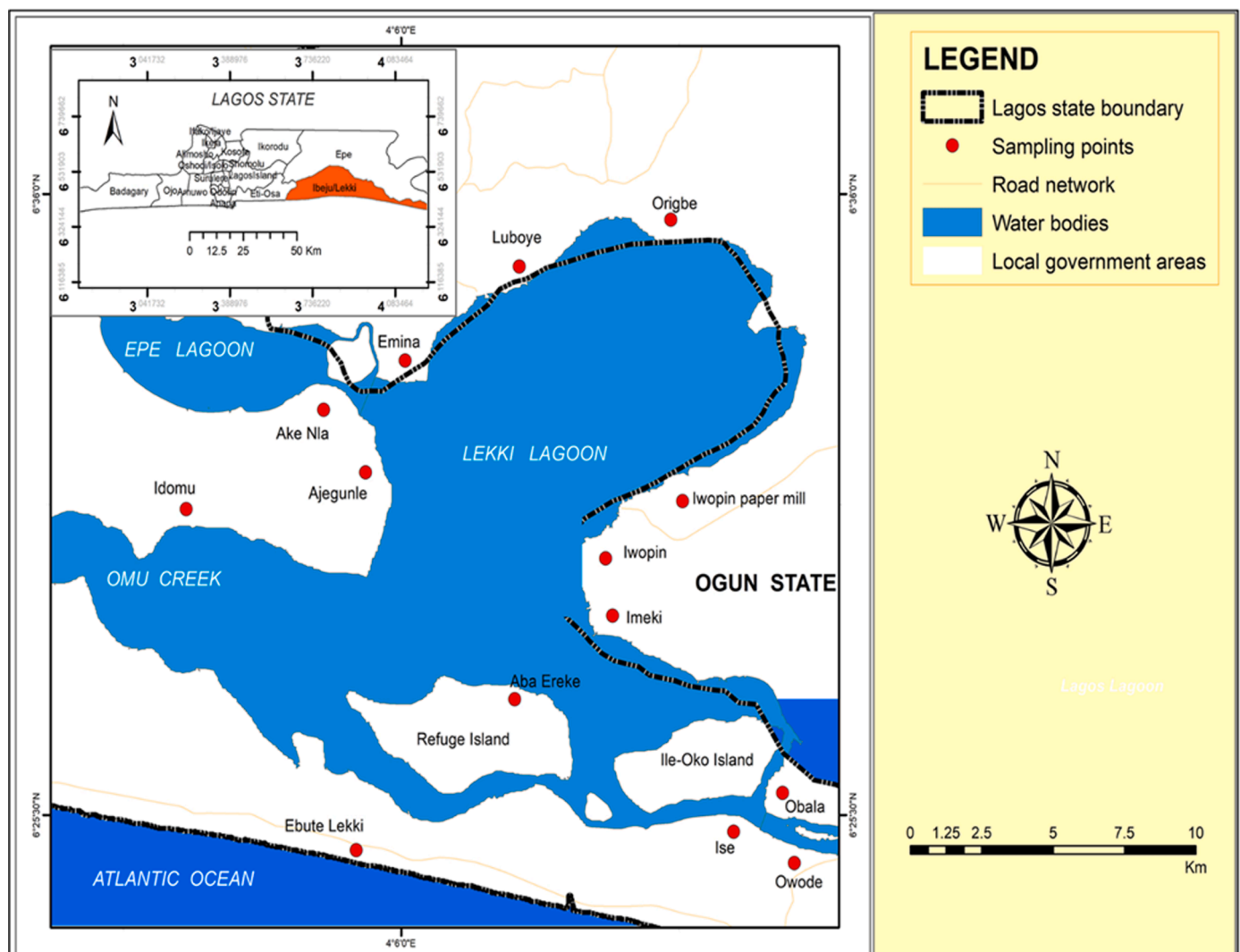

Fig. 1. Map of Lekki Lagoon.

state, Nigeria who used various mesh sizes of fishing traps, cast and gill nets to catch them and keep them alive. Morphometric measurements, sex determination were subsequently done. Fulton's condition factor, given as the percentage of the weight of fish divided by the cubic length of fish was also calculated for every fish.

2.3. Ethical consideration

Ethical permit for this study was obtained from Covenant Health Research Ethics Committee of Covenant University with protocol number CHREC/001/2019, under the National Health Research Ethics Committee number NHREC/25/10/2018.

2.4. Fish dissection and recovery of internal organs

The fish samples collected were labelled and carefully arranged on a table. Each fish was slit open from the rear, while taking care to ensure that the tissues and organs were not damaged during dissection. Thereafter, the gut and liver were removed and placed in petri dishes containing normal saline to provide a suitable condition for the organs. The gastro intestinal tract of each fish was examined for parasites according to Akinsanya, Otubanjo, & Hassan, 2007). The intestines were carefully slit open longitudinally in order to allow the parasite (where present) to emerge easily. Identification of helminth parasite was by the characterized wiggling of the parasite as it emerge from the intestine in the normal saline. Parasites recovered was recorded and kept in saline solution prior to analyses. The identification of parasites was done at the pathology laboratory, Department of Veterinary Pathology, University of Ibadan, Nigeria.

2.5. Analyses of water physico-chemical parameters

Water samples were scooped, using unused, clean 1 L sampling bottles at different sampling locations in the Lagoon. Samples were taken at least twice monthly but also on every fish sampling day. The collected samples were kept in flasks lagged with ice packs and transported to the Department of Marine Sciences of the University of Lagos laboratory, and stored at 4 °C, prior to laboratory analysis. Some water parameters including temperature, salinity, pH, dissolved oxygen and conductivity were measured in-situ with the help of a glass thermometer and a multi-parameter probe (Horiba Water Checker Model U-10). The Van Veen grab was used to collect sediment samples at different locations and were stored immediately in polythene bags prior to analysis. Other parameters were determined according to APHA (1995).

2.6. Determination of metal concentration

Water samples were collected from different locations in sampling site. The samples were thoroughly filtered and acidified by mixing with HNO_3. Sediment samples, 0–5 cm were also taken from the sampling site. The sediment samples were oven-dried overnight at 100 °C, grinded and sieved to get <63 grain size for . One gram of dried samples was thereafter digested with both nitric and perchloric acids (Oregioni & Aston, 1984). The residue was made up to a final volume of 50 ml after addition of 3% HCl and metal analysis was done thereafter.

The fish samples were rinsed with distilled water and removed. The fish liver and intestine was retrieved using stainless steel. About 200 mg of fish tissues were homogenized, digested with concentrated nitric acid and hydrochloric acid in the ratio 3:1, mixed, heated at 200 °C for 30 min and cooled (Jensen, Reutergårdh & Jansson, 1983). The digested sample was further allowed to cool to room temperature. Distilled water was added to the mixture to make up to 50 ml and analysed for Cu, Cr, Zn, Pb, Fe and Cd using Atomic Absorption Spectrophotometer (AAS model Agilent AA55). Similar procedure was followed to prepare an analytical blank. The results were expressed as mg/kg wet weight.

2.7. Collection and examination of fish for microorganisms

Fish samples were transported to the Applied Biology and Biotechnology laboratory of Covenant University, in sterile nylon bags and proper labeling. With the aid of sterile swab sticks, the fish samples were swabbed externally (A) and internally (B). One swab stick was used for the external (skin) while another for the internal sampling. Already prepared sterile Nutrient Agar (NA), MacConkey Agar (MAC), Eosin Methylene Blue (EMB) and Sabouraud Dextrose Agar (SDA) plates were inoculated by striking the swab stick on the plates in a regular pattern. Each plates were appropriately labelled. The NA, MAC and EMB plates after inoculation were incubated at 37 °C for 24 to 48 h while the SDA plates were incubated at 27 °C for 7 days. The NA, MAC, EMB plates were observed after 24 to 48 h of incubation and colonies were counted and identified using Gram stain technique. The SDA plates were examined as from the third day to seventh day of incubation for fungal growth.

2.8. Analysis of proximate composition of Malapterurus electricus

2.8.1. Determination of moisture content
To determine the amount of moisture in fish, five grams of each fish sample was weighed into cleaned and dried glass petri dishes. The dishes and their content were placed inside the Gallemkamp hot air oven at a temperature of 105 °C for 3 hrs. The samples were then cooled in desiccators and weighed. The dishes were placed in the oven for another 30 min. This process was repeated until all the samples in the dishes give a constant weight. The percentage moisture content was calculated by weight differential (AOAC, 2000).

2.8.2. Determination of total ash content
The total ash content was determined using the method described by AOAC (2000). Five grams of the fish was weighed into a previously ignited, cooled and weighed silica dish. The dish and its content was ignited first gently and then at 500 °C for 4 h in a muffle furnace. The dish and its content was cooled in a dessicator and reweighed. It was then returned into the muffle furnace for 30 min, desiccated and reweighed until constant weight. The experiment was carried out in triplicate. Ash content was calculated by calculating the difference in weight and converting to percentage

2.8.3. Determination of crude protein content
The protein content determination was done using micro Kjedhal method as described by AOAC (2000) which involve wet digestion, distillation, and titration. The protein content was determined by weighing 3 g of fish into digestion tube with 25 ml concentrated sulphuric acid and one catalyst tablet. This was heated and the resulting digest was diluted with water. Ten milliliter of 40% NaOH and 5 ml of $Na_2S_2O_3$ was added, and the component was diluted into 10 ml of Boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 N standard HCl using 25 ml burette. A blank was prepared by omitting the sample. Value obtained was multiplied by conversion factor and the result expressed as the amount of crude protein in percentage.

2.8.4. Determination of crude fat content
The crude fat content was determined using Soxhlet extractor (AOAC, 2000). Approximately 2 g of fish was placed in a fat-free extraction thimble, plug lightly with cotton wool. The thimble was placed in the extractor and petroleum ether was added until it siphons over once. More petroleum ether was added until the barrel of extractor is half full. The solvent was allowed to boil gently for the system to siphon over at least ten times. Fat content was calculated by differences in weight and converted into percentage.

2.8.5. Determination of crude fiber
The crude fiber content was determined using the method described

by AOAC (2000). Approximately, 3 g of fish were weighed and extracted with the petroleum ether. It was allowed to boil (under reflux condenser) for 40 min. Filter paper was placed in the funnel and the sample was drained by applying suction. The insoluble material was washed first with boiling water, then with 1% HCl, twice with alcohol and thrice with ether. The filter paper was dried at 100 °C to a constant weight. The paper and the contents was weighed then incinerated to ash and the remaining ash was weighed. The difference between the weight of the paper plus the insoluble material and that of the ash represents the fiber content.

2.9. Quality assurance

Analytical grade reagents were used all through the study. Glass materials were soaked and rinsed in 10% HNO_3 for 24 h and in distilled water respectively. This procedure was repeated replacing nitric acid with 0.5% $KMnO_4$ solution. Precision and accuracy of procedure were verified by using certified reference material DORM-3. Recovery percentages of analytical results within the range of 95–100% were obtained for all the metals studies.

2.10. Statistical analysis

Mean values of result from the study were subjected to One-way Analysis of Variance (ANOVA) to show significant differences using the SPSS 20.0 version tool packages (Ozdamar, 1991). Means were compared using the Duncan Multiple Range Test. All analyses were tested at significant level of 1% ($P < 0.01$).

3. Results

The result of some of the physico-chemical parameters of water that were measured and their respective values are as presented in Table 1. Some of the parameters analysed in water included pH, temperature, turbidity, electrical conductivity, total dissolved solids and dissolved oxygen.

Of the total number of fish sampled, one intestinal parasite species, *Electrotaenia malopteruri* a cestode was found to infect *Malapterurus electricus*. Table 2 shows parasitic abundance and prevalence of infection from the total number of samples with respect to length while the pattern of parasitic infection in *Malapterurs electricus* with respect to weight of fish is as presented in Table 3. A total of eighty five parasites were recovered, sixty six in the males and nineteen in the females. The middle-sized fish have higher prevalence of infection and parasitic load. The various length groups and weight groups show variations in abundance and prevalence of infection. The highest parasite load was found in the fish length and weight groups 20 cm – 30 cm, 41 – 80 g for both males and females while the highest prevalence of infection was also within this range for the two sexes. The total prevalence of infection is 36%.

The condition factor of the fish throughout the study period is presented in Table 4. The differences in the condition factors of both the male and female fish were not significant in all the months. The months of October and November showed the highest condition factors.

Table 1
Physicochemical Parameters of water measured in the Lekki lagoon and their values.

Parameter	Value
pH	6.83±0.75
Electrical Conductivity (μS/cm)	221.4 ± 11.19
Total Dissolved Solids (mg/l)	102±9.51
Temperature	27.13±2.83
Turbidity (ntu)	45.46±12.23
Dissolved Oxygen (mg/l)	9.99±2.08

Values given as mean±SD.

Table 2
Relative abundance of recovered parasites and prevalence of infection in *Malapterurus electricus* from Lekki Lagoon with relation to standard length.

	Standard Length (cm)	Number Examined	No Infected	Prevalence (%)	Parasite Load
Male	10–20	31	7	8.1	2
	21–30	13	8	9.3	55
	31–40	9	3	3.5	9
Female	10–20	0	0	0	0
	21–30	29	11	12.8	17
	31–40	4	2	2.3	2
Both sexes	10–20	31	7	8.1	2
	21–30	42	19	22.1	72
	31–40	13	5	5.8	11

Table 3
Relative abundance of recovered parasites and prevalence of infection in *Malapterurus electricus* from Lekki Lagoon with relation to weight.

	Weight (g)	Number Examined	No Infected	Prevalence (%)	Parasite Load
Male	10–40	20	4	4.7	2
	41–80	11	10	11.6	35
	81–120	17	3	3.5	19
	121–160	5	1	1.2	10
Female	10–40	0	0	0	0
	41–80	20	7	8.1	8
	81–120	8	4	4.7	9
	121–160	5	2	2.3	2
Both sexes	10–40	20	4	4.7	2
	41–80	31	17	19.8	43
	81–120	25	7	8.1	28
	121–160	10	3	3.5	12

Table 4
Monthly mean condition factor of male and female *Malapterurus electricus*.

Months	Male	Female
July	1.85±0.10[a]	1.84±0.11[a]
August	1.61±0.08[a]	1.68±0.07[a]
September	1.75±0.05[a]	1.83±0.07[a]
October	2.11±0.05[a]	2.21±0.08[a]
November	2.12±0.11[a]	2.15±0.12[a]

The concentrations of the different metals analysed in water and sediment samples are as presented in Table 5. aluminum and nickel had the highest and lowest concentration respectively in the sediment samples while in the water samples, manganese and lead had the highest and lowest concentrations respectively. Furthermore, there were no significant differences between water and sediment concentrations of barium, copper, nickel and zinc.

Table 5
Elemental analysis of water and sediments in the Lagos lagoon.

Metal	Water (mg/l)	Sediment (mg/kg)
Al	0.044±0.01[a]	142.23±4.01[b]
Ba	0.108±0.02[a]	0.098±0.01[a]
Cd	0.054±0.03[a]	0.219±0.02[b]
Cr	0.048±0.01[a]	0.627±0.01[b]
Cu	0.043±0.01[a]	0.078±0.03[a]
Fe	0.556±0.02[a]	56.72±2.51[b]
Mn	1.215±0.05[a]	40.55±1.45[b]
Ni	0.023±0.01[a]	0.038±0.01[a]
Pb	0.021±0.01[a]	0.762±0.02[b]
Zn	0.422±0.04[a]	0.448±0.12[a]

Values (mean±SD) with the same superscript on the same row are not significantly different.

The metals analysed and their concentrations in the liver and intestine of *Malapterurus electricus* is presented in Table 6. There are no significant differences in the concentrations of Cu and Pb in the two fish tissues. The other metals showed significantly higher values in the intestine compared to the liver. Cadmium and lead showed the highest and lowest concentration in the intestine, while in the liver, zinc and lead had the highest and lowest concentration of all metals.

The average proximate composition of *Malapterurus electricus* is presented in Table 7. As expected, the moisture content is the highest, followed by crude protein. Ash content is the least of all the parameters.

Results of the assessment of microbial load is presented in Table 8. Different microorganisms were isolated from fish samples. Total bacteria counts of 30.6×10^4 cfuml^{-1} and 5.5×10^4 cfuml^{-1} were recorded in the skin and intestine of the fish respectively. Bacteria species isolated from both the internal and external parts of *Malapterurus electricus* include *Escherichia coli*, *Micrococcus* spp. and *Pseudomonas* spp. *Klebsiella* spp., *Samonella* spp., *Proteus* spp. were observed only in the intestine of fish while *Staphylococcus* spp. and *Bacillus* spp. were found to occur only on the skin of the fish. Furthermore, while the fungal isolates found in the fish skin are *Rhizopus* spp. and *Mucor* spp. only the latter was found in the intestine.

4. Discussions

It is important to measure physico-chemical parameters of water, in order to determine the quality of water which is very key to survival and yield of aquatic organisms especially fish (Makori, Abuom, Kapiyo, Douglas & Dida, 2017). The pH of water in this study (6.83) is healthy for fish and within recommended limit. Same can be said of the recorded temperature value. The electrical conductivity value shows that there is good ionic solution in the water. The dissolved oxygen content is high. This may be because it is a cold water body, where dissolved oxygen levels is generally expected to be higher than in warmer waters. It may also be an indication of turbulence and regular windy activities in the lagoon. High turbidity may mean there are a lot of materials washed into the lagoon from the surrounding areas, which may also further lead to high nutrient content.

Reports exist of the detection of heavy metals in water, sediment and in tissues of different fish species from the Lekki lagoon (Abdul et al., 2019; Akinsanya & Kuton, 2016). Our findings in this study further supports previous reports of heavy metal pollution in this body of water. Although there were significant differences in the concentrations of most of the metals comparing water and sediments, a lot of these values are below regulatory limits especially the toxic metals. However, the concentration of the selected heavy metals were lower in the fish liver and intestine than in sediments and water sample, confirming the notion that high metallic concentration in water and sediment does not directly pose toxic threat to the fish, particularly in cases of insignificant bioaccumulation (Hassan, Saleh & Salman, 2010).

The concentrations of the metals in the tissues of *Malapterurus electricus* were also all below regulatory limits. This is different from what was reported in a recent study by Akinsanya, Ayanda, Fadipe, Onwuka and Saliu (2020) who reported values of toxic heavy metals in the tissues of *Heterotis niloticus* in the same lagoon that are higher than recommended values. This may mean that different fish species have differing

Table 6
Mean elemental concentrations (±SD) in the organs of *Malapterurus electricus*.

Metals (mg kg^{-1})	Liver	Intestine
Zn	0.257±0.16[a]	0.575±0.16[b]
Cd	0.02±0.16[a]	0.865±0.16[b]
Fe	0.115±0.16[a]	0.151±0.16[b]
Cu	0.023±0.16[a]	0.033±0.16[a]
Pb	0.0015±0.001[a]	0.0015±0.001[a]
Cr	0.011±0.16 [a]	0.054±0.16[b]

Values with the same superscript on the same row are not significantly different.

Table 7
Average Proximate Values (±SD) of *Malapterurus electricus*.

Proximate Parameters (%)	Values
Crude Protein	15.91 ± 1.23
Moisture	80.70 ± 1.25
Ash	1.26 ± 0.56
Fat	1.56 ± 1.02

Table 8
Microbes in the External and Internal Parts of *Malapterurus electricus*.

Microorganisms	Intestine	Skin
Proteus sp.	+	−
Micrococcus sp.	+	+
Klebsiella sp.	+	−
E. coli	+	+
Pseudomonas sp.	+	+
Salmonella sp.	+	−
Staphylococcus aureus	−	+
Bacillus sp.	−	+
Rhizopus sp.	−	+
Mucor sp.	+	+

+ = Present; - = Absent.

abilities to eliminate or accumulate these metals in their bodies. Even within the same species, different tissues accumulate the metals differently as can be seen in Table 5. The intestine showed significantly higher concentrations of metals than the liver with the exception of lead and iron. The liver is the most vital organ for detoxification and storage of heavy metal pollutants (Ardeshir, Movahedinia, & Rastgar, 2017). Hence the low heavy metal bioaccumulation in the liver suggests that *Malapterurus electricus* have a good mechanism for detoxifying heavy metal pollutants accumulated from the environment. The ability of the liver to effectively regulate heavy metal accumulation may be attributed to the synthesis of metallothionein proteins (MTs). MTs are metal binding proteins that bind and detoxifies metal ions due to their high affinity for metallic ions (Yousafzai and Shakoori, 2008).

Electrotaenia malapteruri is a cestode specific to *Malapterurus electricus*. It has been previously reported as parasitizing *Malapterurus electricus* (Akinsanya, Otubanjo, & Hassan, 2007). The overall prevalence of infection, 36% as reported in this study is similar to one reported by Akinsanya, Otubanjo, & Hassan, 2007) who reported a prevalence of infection of 37% parasitic infection in *Malapterurus electricus*. The low prevalence may be due to food availability. Another reason for this may be the nature of the life cycle of the parasites. The females have a higher prevalence of infection, which may be due to random selection of samples and probably more active feeding than the males. Control of hormonal activities and sampling season may also be a factor upon which the difference in prevalence of infection between the sexes can be predicated (Ayanda, 2009b). The sub-adults also have the highest infection prevalence compared with the other age groups. This follows previous reports (Ayanda, 2008; Oniye, Adebote & Ayanda, 2004) of fish in this age group being the most active feeders, feeding a wide range of food items thereby increasing their chances of contact with parasites.

Microbiota in fish gut enhances metabolism and assist in enzymatic digestion of food. Associated symbiotic fish gut microbiota play a role in nutritional provisioning, metabolic homeostasis and immune defense (Gómez & Balcázar, 2008; Sullam et al., 2012). The skin normal flora act as first line defense against invasive microbial species that pose threat to the fish by competing with invading pathogens for nutrient and space. The gut microbiota as observed in this study comprises seven species of bacteria and two fungi species, supporting the notion that fish microbiome can be diverse, cutting across protoctista, bacteria, fungi, yeasts, viruses, and Archaea (Merrifield & Rodiles, 2015). However, there are more bacteria species recorded. According to Rombout, Abelli, Picchietti, Scapigliati and Kiron (2011), bacteria are the most dominant

microorganisms in fish intestine.

According to International Commission on microbiological specification for food (ICMSF, 1998) the maximum recommended bacteria count for good quality product was 5.0×10^5 cfuml^{-1}. The bacteria load obtained from the fish in this study were lower than the recommended values which suggests that the fish used in the study is suitable for human consumption. Result of this study also showed that the external part harbored more microorganisms than the internal part, probably indicating poor post-harvest handling.

Malapterurus electricus is a carnivore, using electric currents to shock and capture its host. Of some of the bacteria species that have reported to be present in the gut of carnivorous fish (Floris, Manca & Fois, 2013; Ransom, 2008; Sun, Yang, Ling, Chang, & Ye, 2009) only E. coli, Pseudomonas species and Bacillus species are reported in this study. Differences in comparison of results in studies such as these could arise due to diversity of species studies, methods of sample collection and even analysis (Egerton, Culloty, Whooley, Stanton & Ross, 2018). Furthermore, it has been reported that quantity and quality of diet could also affect the composition and diversity of gut microbial communities (Zha, 2017).

Stress decreases the diversity in gut microbial communities and affects their composition. That diversity of microbiota in the gut of fish in this study is not affected may mean that the fish is not stressed either from predation or from anthropogenic activities (Zha, 2017). This can be further corroborated by the condition factor which is greater than 1 in all cases indicating that the fish are in good health condition. The higher condition factor in the later months of study may be attributed to factors such as changes in cycle of reproduction, food availability as well as prevailing environmental factors (Morato et al., 2001).

Analysis of the nutritional component of fish is vital in ensuring that it meets the food regulation requirements (Watermann, 2000). With the exception of ash content where (Ayanda et al. 2019) reported value of 3.95%, all other proximate parameters were similar to those reported in *Malapterurus electricus* sampled from Ogun River by the same author. Differences observed in the nutritional composition in fish could be because of the rate in which these components are accessible in the water body (Yeannes & Almandos, 2003), and the capability of the fish to take up and convert the vital nutrients from the diet or the water bodies.

5. Conclusion

The present study confirms parasitic infection in *Malapterurus electricus* but at a low prevalence. The heavy metals detected in water, sediment and fish tissues were also below regulatory limits. The condition factor of fish is also above the threshold for wellness. All these points to the wellbeing of the fish *Malapterurus electricus* in the sample area despite several reports of anthropogenic activities impacting the water and biota. However, similar studies on multiple fish species and over different seasons may be necessary to further ascertain our results in this study.

References

Abdul, W. O., Oguntuase, K. E., Omoniyi, I. T., Bada, S. B., Adekoya, E. O., Bashir, A. O, et al. (2019). Dynamics of heavy metal pollution in tropical lagoon of Gulf of Guinea, West Africa. *Journal of Applied Sciences and Environmental Management, 2,* 985–993. 10.4314/jasem.v23i5.32.

Abolagba, O. J., & Melle, O. O. (2008). Chemical composition and keeping qualities of Scaly Fish Tilapia, Oreochromis niloticus smoked with two energy sources. *African Journal of General Agriculture, 4,* 113–117.

Akinsanya, B., Ayanda, O. I., Fadipe, A. O., Onwuka, B., & Saliu, J. K. (2020). Heavy metals, parasitologic and oxidative stress biomarker investigations in *Heterotis niloticus* from Lekki Lagoon, Lagos, Nigeria. *Toxicology Reports,* 1075–1082. https://doi.org/10.1016/j.toxrep.2020.08.010.

Akinsanya, B., & Kuton, M. P. (2016). Bioaccumulation of heavy metals and parasitic fauna in Synodontis clarias (Linnaeus, 1758) and Chrysichthys nigrodigitatus (Lacepede, 1803) from Lekki Lagoon, Lagos, Nigeria. *Asian Pacific Journal of Tropical Diseases,* 615–621. doi.org/10.1016/s2222-1808(16)61096-4.

Akinsanya, B., Otubanjo, O. A., & Hassan, A. A. (2007). Helminth Parasites of Malapterurus electricus (Malapteruridae) From Lekki Lagoon, Lagos, Nigeria. *Journal of American Science, 3,* 1–6.

American Public Health Association (APHA). (1995). *Standard methods for the examination of water and waste water* (19th edition,, 5 pp. 24–26). New York: APHA/AWWA/WPCF.

Ardeshir, R. A., Movahedinia, A., & Rastgar, S. (2017). Fish liver biomarkers for heavy metal pollution: A review article. *American Journal of Toxicology, 2,* 1–8.

Association of Official Analytical Chemists. (2000). *Official methods of analysis* (20th Ed). Gaithersburg, MD: AOAC International.

Ayanda, O. I. (2008). Comparison of Parasitic Helminth Infection between the different age groups of *Clarias gariepinus* from Asa dam, Ilorin, North-Central Nigeria. *African Journal of Environmental Science and Technology, 2,* 404–406.

Ayanda, O. I. (2009b). Comparison of Parasitic Helminth Infection between the sexes of Clarias gariepinus from Asa dam, Ilorin, North-Central Nigeria. *Scientific Research and Essays, 4,* 357–360.

Ayanda, O. I., Ekhator, U. I., & Bello, O. A. (2019). Determination of selected heavy metal and analysis of proximate composition in some fish species from Ogun River. *Southwestern Nigeria. Heliyon,* e02512. https://doi.org/10.1016/j.heliyon.2019.e02512.

Bentzon-Tilia, M., Traving, S. J., Mantikci, M., Knudsen-Leerbeck, H., Hansen, J. L. S., Markager, S., et al. (2015). Significant N$_2$ fixation by heterotrophs, photoheterotrophs and heterocystous cyanobacteria in two temperate estuaries. *ISME Journal,* 273–285. 10.1038/ismej.2014.119.

Bichi, A. H., & Yelwa, S. I. (2010). Incidence of piscine parasites on the gill and gastrointestinal tract of Clarias gariepinus (Teugels) at Bagauda Fish Farm, Kano. *Bayero Journal of Pure Applied Sciences,* 104–107. https://doi.org/10.4314/bajopas.v3i1.58732.

Echi, P. C., Eyo, J. E., & Okafor, F. C. (2009). Co-parasitism and morphormetrics of three clinostomatids Digenea: Clinostomatidae; in Sarotherodon melanotheron from a tropical freshwater lake. *Animal Research International,* 982–986. https://doi.org/10.4314/ari.v6i2.48129.

Egerton, S., Culloty, S., Whooley, J., Stanton, C., & Ross, R. P. (2018). The gut microbiota of marine fish. *Frontiers in Microbiology,* 873. https://doi.org/10.3389/fmicb.2018.00873.

Emikpe, B. O., Adebisi, T., & Adedeji, O. B. (2011). Bacteria load on the skin and stomach of Clarias gariepinus and Oreochromis niloticus from Ibadan, South West Nigeria: Public Health Implications. *Journal of Microbiology and Biotechnology Research, 1,* 52–59.

Floris, R., Manca, S., & Fois, N. (2013). Microbial ecology of intestinal tract of gilthead sea bream (Sparus aurata Linnaeus, 1758) from two coastal lagoons of Sardinia (Italy). *Transitional Waters Bulletin,* 4–12. https://doi.org/10.1285/i1825229Xv7n2p4.

Gómez, G. D., & Balcázar, J. L. (2008). A review on the interactions between gut microbiota and innate immunity of fish. *FEMS Immunology and Medical Microbiology, 5,* 145–154. 10.1111/j.1574-695X.2007.00343.x.

Gupta, N., Khan, D. K., & Santra, S. C. (2012). Heavy metal accumulation in vegetables grown in a long-term wastewater-irrigated agricultural land of tropical India. *Environmental Monitoring and Assessment, 18,* 6673–6682. https://doi.org/10.1007/s10661-011-2450-7.

Hassan, A. A., Akinsanya, B., & Adegbaju, W. A. (2010). Impacts of helminth parasites on Clarias gariepinus and Synodontis clarias from Lekki Lagoon, Lagos, Nigeria. *Report and Opinion, 2,* 42–48.

Hassan, F. M., Saleh, M. M., & Salman, J. M. (2010). A study of physicochemical parameters and nine heavy metals in the Euphrates River, Iraq. *E-Journal of Chemistry,* 685–692. https://doi.org/10.1155/2010/906837.

Holden, M., & Reed, W. (1972). *West african freshwater fish* (p. 68). London: Longman.

ICMSF. Fish and Fish Products. In: Microorganisms in foods: *Microbial ecology of food communities,* ICMSF ((1998).Ed.). Blackie Academic and Professional, London, UK., pp. 130–189.

Jensen, S., Reutergårdh, L., & Jansson, B. (1983). FAO/SIDA. Manual of methods in aquatic environment research. Part 9. Analyses of metals and organochlorines in fish. *FAO Fisheries Technical Paper, 21,* 21–33.

Lafferty, K. D. (2008). Ecosystem consequences of fish parasites. *Journal of Fish Biology, 7,* 2083–2093. 10.1111/j.1095-8649.2008.02059.x.

Leveque, C., Paugy, D., & Teugels, G. G. (1991). Annotated checklist of the freshwater fishes of the Nilo–Sudanriver basins in African. *Revue d'Hydrobiologie Tropicale, 2,* 131–154.

Liu, X, Lu, S., Guo, W., Xi, B., & Wang, W. (2018). Antibiotics in the aquatic environments: A review of lakes. *China. Science of the Total Environment, 62,* 1195–1208. https://doi.org/10.1016/j.scitotenv.2018.01.271.

29 Makori, A. J., Abuom, P. O., Kapiyo, R., Douglas, N. A., & Dida, G. O. (2017). Effects of water physico-chemical parameters on tilapia (Oreochromis niloticus) growth in earthen ponds in Teso North Sub-County, Busia County. *Fisheries and Aquatic Sciences, 2,* 30. doi.org/10.1186/s41240-017-0075-7.

Meijide, F. J., Da Cuna, R. H., Prieto, J. P., Dorelle, L. S., Babay, P. A., & Lo Nostro, F. L. (2018). Effects of waterborne exposure to the antidepressant fluoxetine on swimming, shoaling and anxiety behaviours of the mosquitofish Gambusia holbrooki. *Ecotoxicology and Environmental Safety, 16,* 646–655. https://doi.org/10.1016/j.ecoenv.2018.07.085.

31 Merrifield, D.L., & Rodiles, A. (2015).The fish microbiome and its interactions with mucosal tissues," in ed. E.Peatman (San Diego, CA: Academic Press, pp. 273–295.

Morato, T., Afonso, P., Loirinho, P., Barreiros, J. P., Sanstos, R. S., & Nash, R. D. M. (2001). Length-weight relationships for 21 costal fish species of the Azores, North-eastern Atlantic. *Fisheries Research, 5,* 297–302. doi.org/10.1016/S0165-7836(00)00215-0.

Nmor, J. C., Egwunyenga, A. O., & Ake, J. E. G. (2004). Observation of the intestinal helminths parasites of cichlids in the upper reaches of River Orogodo, a freshwater body in Delta State. *Southern Nigeria. Tropical Freshwater Biology, 1*, 131–136. 10.4 314/tfb.v12i1.20883.

Oniye, S. J., Adebote, D. A., & Ayanda, O. I. (2004). Helminth Parasites of *Clarias gariepinus* (TEUGELS) in Zaria, Nigeria. *Journal of Aquatic Sciences, 1*, 71–75. https://doi.org/10.4314/jas.v19i2.20027.

Oregioni, B., & Aston, S. R. (1984). *The determination of selected trace metals in marine sediments by flameless/flame atomic absorption spectrophotometry*. Monaco: IAEA Monaco Laboratory. Internal Report.

Ozdamar, K. (1991). *Biostatistics with spss* (pp. 2–23). Eskisehir: Kann Pres.

Ransom, B. L. (2008). *Intestinal microbial community composition of six actinopterygii fish species in the Southeastern United State. a thesis submitted to the graduate faculty of the University of Georgia in partial fulfillment of the requirements for the degree master of science*. Athens, GA: University of Georgia.

Rombout, J. H., Abelli, L., Picchietti, S., Scapigliati, G., & Kiron, V. (2011). Teleost intestinal immunology. *Fish and Shellfish Immunology, 3*, 616–626. https://doi.org/10.1016/j.fsi.2014.08.020.

Schmeller, D. S., Loyau, A., Bao, K., Brack, W., Chatzinotas, A., De Vleeschouwer, F., et al. (2018). People, pollution and pathogens – Global change impacts in mountain freshwater ecosystems. *Science of the Total Environment, 622–62*, 756–763. https://doi.org/10.1016/j.scitotenv.2017.12.00.

40   Shah, A. I. (2017). Heavy metal impact on aquatic life and human health–an over view. In *IAIA17 Conference Proceedings| IA's Contribution in Addressing Climate Change 37th Annual Conference of the International Association for Impact Assessment* (pp. 4–7). Apr.

Singh, A., Sharma, R. K., Agrawal, M., & Marshall, F (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. *Tropical Ecology, 5*, 375–387.

Skelton, P. H. (1993). *A complete guide to the freshwater fishes of Southern Africa* (p. 388). Southern Book Publishers.

Sullam, K. E., Essinger, S. D., Lozupone, C. A., O'Connor, M. P., Rosen, G. L., Knight, R., et al. (2012). Environmental and ecological factors that shape the gut bacterial communities of fish: A meta-analysis. *Molecular Ecology, 2*, 3363–3378. https://doi.org/10.1111/j.1365-294X.2012.05552.x.

Sun, Y., Yang, H., Ling, Z., Chang, J., & Ye, J. (2009). Gut microbiota of fast and slow growing grouper *Epinephelus coioides*. *African Journal of Microbiology Research, 3*, 637–640.

Teugels, G. G. (1996). Taxonomy, phylogeny and biogeography of catftshes (Ostariophysi,Siluroidei). *an overview. Aquatic Living Resources, 9*, 9–34.

Van der Oost, R., Beyer, J., & Vermeulen, N. P. E. (2012). Fish bioaccumulation and biomarkers in environmental risk assessment: A review. *Environmental Toxicology and Pharmacology, 1*, 57–149. https://doi.org/10.1016/S1382-6689(02)00126-6.

Waterman, J. J. (2000). *Composition and quality of fish*. Edinburgh: Torry Research Station.

Yeannes, M. I., & Almandos, M. E. (2003). Estimation of fish proximate composition starting from water content. *Journal of Food Composition and Analysis, 1*, 81–92. https://doi.org/10.1016/S0889-1575(02)00168-0.

Yousafzai, A., & Shakoori, A. R. (2008). Heavy metal accumulation in the Gills of an endangered South Asian Freshwater Fish as Indicator of Aquatic pollution. *Pakistan Journal of Zoology, 4*, 423–430.

Zha, Y. (2017). *Assembly of gut microbial communities in freshwater fish and their roles in fish condition. digital comprehensive summaries of Uppsala dissertations from the Faculty of Science and Technology 1473* (p. 42). Uppsala: Acta Universitatis Upsaliensis.

Zhao, X. M., Yao, L. A., Ma, Q. L, Zhou, G. J., Wang, L., Fang, Q. L, et al. (2018). Distribution and ecological risk assessment of cadmium in water and sediment in Longjiang River, China: Implication on water quality management after pollution accident. *Chemosphere, 19*, 107–116. https://doi.org/10.1016/j.chemosphere.2017.11.127.

Zhu, S., Zhang, Z., & Zagar, D. (2018). Mercury transport and fate models in aquatic systems: A review and synthesis. *Science of the Total Environment, 63*, 538–549. https://doi.org/10.1016/j.scitotenv.2018.04.397.