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Bioaccumulation of heavy metals and parasitic fauna in *Synodontis clarias* (Linnaeus, 1758) and *Chrysichthys nigrodigitatus* (Lacepede, 1803) from Lekki Lagoon, Lagos, Nigeria

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ABSTRACT

Objective: To study the bioaccumulation of heavy metals from *Synodontis clarias* (*S. clarias*) and *Chrysichthys nigrodigitatus* (*C. nigrodigitatus*) with their parasitic fauna.
Methods: A total of 50 specimens of each fish species (n = 100) were examined. The fishes were subjected to parasitological investigation while 3 g of intestinal tissue of *S. clarias* and *C. nigrodigitatus* samples were digested with nitric acid (10 mL). The tissues were then heated until brown fumes disappeared. The samples were allowed to cool and distilled water was added to make up to 50 mL in a standard flask. The filtrate was examined using the atomic absorption spectrometer. The fish hosts were weighed and measured with the aid of digital weighing balance and measuring board, respectively.
Results: The *Chi*-square distribution was significant at 0.01 level ($\chi^2 = 2.16$, $P < 0.01$). A nematode of the family Camallanidae (*Procamallanus* spp.) was found in *S. clarias* and a trematode (*Siphodera ghanensis*) was found in *C. nigrodigitatus*. The total lengths of *C. nigrodigitatus* in females and males were (15.05 ± 3.27) cm and (20.35 ± 4.20) cm ($P < 0.01$), respectively. Also the total lengths of *S. clarias* in females and males were (21.07 ± 2.80) cm and (20.76 ± 2.37) cm ($P < 0.01$), respectively. The mean value for the condition factor of both *S. clarias* and *C. nigrodigitatus* were more than 2.0. The concentrations of the trace elements in the fishes were Pb > Zn > Mn > Fe > Cd (not detected) and Mn > Zn > Fe > Pb > Cd (not detected), respectively, while in the nematode, *Procamallanus* spp. and trematode, *Siphodera* spp. were Pb > Mn > Fe > Zn > Cd and Mn > Fe > Zn > Pb > Cd, respectively. In the water and sediment, the distribution of heavy metals were Fe > Mn > Zn > Pb > Cd and Fe > Mn > Pb > Zn > Cd, respectively.
Conclusions: The findings of the concentrations of the trace elements in the aquatic habitat as well as the sediment were below the permissible limit of Federal Ministry of Environment. These findings confirmed that the aquatic habitat was adequate for fishing activity and that the consumption of fish species therein are safe. However, it should be noted that there was bioaccumulation of trace elements in the fish tissues which should not pose any danger to man. Therefore, a regular monitoring of the levels of trace elements in the water body as well as in the fauna should be regularly undertaken.

1. Introduction

Parasitic organisms are found everywhere in nature[1]. It has been reported that parasites are important sentinels of ecosystems polluted with contaminants in the use of cestode from the yellow fish *Labeobarbus kimberleyensis* reported bioaccumulation of heavy metals in the parasites on effects of municipal effluents reported that it impaired food webs[2,3]. Several reports have confirmed the susceptibility of parasitic organisms to contaminants such as trace elements[4]. The fact that the trace elements are indestructible through all means and their persistent accumulation in the environment makes them harmful to the aquatic environment and consequently to humans who consumed them as sources of food. Since parasites are in direct contact with the contaminants in the environment, they may be easily susceptible to heavy metals accumulation[4]. In the Lagos Lagoon, metals are reported to be well concentrated in the water, sediments and biota[5]. Using parasites as bioindicators of heavy metals accumulation is a promising approach[6]. This is due to their capacity to bioconcentrate trace

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elements[6]. Endoparasitic infections is an indication of the quality of the water since these infections are more pronounced in polluted waters[7]. Bush *et al.*[8] reported that parasites usually remained permanently in their hosts as a survival strategy.

Parasites affect fish health, growth and survival. They are very common throughout the world in fishes[9]. There are some parasites that can be found on the skin and gills, while some are located in the visceral organs of fishes. The presence of parasites in a particular fish is a function of their habitats, life cycle, ability to survive host immune assault, and associated function in ecosystems among others[10]. However, in case where there is adverse stress predisposing factors, parasites attack their host resulting in gross mortalities. So, the presence of parasites in fishes in a particular aquatic system is a confirmation of environmental stress. For example, there are more ectoparasites in a polluted water than endoparasites and so there will be fewer ectoparasites than endoparasites in a polluted system, and vice versa[10]. Most fish species can act as definitive or intermediate hosts. Beside other factors, they are also susceptible to pathogenic bacteria, chemical residues, pesticides and trace metals[11].

Parasites are good sentinels of environmental quality due to their ability to respond to anthropogenic pollution. The link between pollution and parasites as good indicators of environmental quality has been reported by several authors in the past[2,12]. It has also been reported that parasites have the capacity to interfere with the uptake and accumulation of contaminants in their fish hosts[12]. Bivalve mollusks are commonly used as sentinel organisms to monitor the concentrations of metals in the aquatic environment. It has been reported that intestinal acanthocephalans of fishes can accumulate heavy metals in higher concentrations than those in the host tissues or the environment[12,13].

Studies have reported that heavy metal concentrations in parasites of vertebrates, mainly fishes, are higher than those found in the tissues of their hosts[12-14]. Knowledge of fish parasites is important to depict the condition factor of the fish and also to solve ecological problems in the water body. This interest in fish parasitological research is related to the high intensity of parasites commonly found in or on freshwater and marine fishes.

The importance of parasites as being used as indicators of environmental quality has gained considerable attention over the last few years. This is as a result of the variety of ways in which they respond quickly to man-made pollution. Since heavy metals can easily accumulate in the tissues of aquatic animals as well as their parasitic fauna, this should be a public health concern to both humans and animals[15]. However, much work has not been done on trace elements concentrations in terrestrial animals. Parasites are important in many ways as “effect indicators” and the changes of the whole population structure can be monitored through them based on the magnitude of pollution in the particular water body. However, the use of parasites as effect indicators is with its attendant problems because of factors affecting their populations. Studies on the diversity of fish parasites in different hosts are important. It is, however, difficult to draw any conclusion of specific contaminant in the environment. Parasitic organisms are efficient accumulation indicators. This has been confirmed as a result of their accumulation of contaminants from industrial and agricultural processes causing adverse effects on aquatic biota as well as human health[15]. Parasite metrics have been linked to some environmental conditions, and they can indicate different pollutants such as trace metal concentrations, industrial and sewage pollution and also aquatic pollution by runoff fertilizers. Parasitic infections have been attributed to man-made impact and environmental changes also in aquatic habitats. Accumulation of trace metals in the tissues of aquatic fauna as well as in their parasites is linked to the concentrations of these contaminants in the water and in the sediment which are also dependent on the exposure period.

2. Materials and methods

2.1. Study area

The study area is Lekki Lagoon located in Lagos State, Nigeria. The lagoon is between longitudes 4°0'00"–4°15'0" E and latitudes 6°25'0"–6°35'0" N. The lagoon is dependent upon many villagers of Lagos State. The surface area is 247 km with a depth of 6.4 m. Some parts of the lagoon are shallow. The Lekki Lagoon is a part of a the complicated system of waterways which is a combination of other lagoons around the Lagos metropolis that are found along the part of the land adjoining of South-western Nigeria. This is actually from the southern Benin border to the Niger Delta which is about 200 km. Both rivers Oni and Oshun discharge to the northeastern and into northwestern parts of the lagoon, respectively. Both dry and rainy seasons are experienced in the lagoon typical of the southern part of Nigeria. The flora around the lagoon is characterized by *Raphia* palms, *Raphia sudanica*, and oil palms, *Elaeis guneensis*. Grasses are found on the periphery of the lagoon while coconut palms *Cocos nucifera* are widespread in the surrounding villages. There fishes in the lagoon includes *Heterotis niloticus, Gynmnarchus niloticus, Clarias gariepinus, Malapterurus electricus, Synodontis clarias* (*S. clarias*)*, Chrysichthys nigrodigitatus* (*C. nigrodigitatus*)*, Parachanna obscura, Mormyrus rume, Calabaricus calamoichthys, Tilapia zillii, Tilapia galilae, Hemichromis fasciatus* and *Sarotherodon melanotheron*. Figure 1 shows the map of the Lekki Lagoon, Lagos, Nigeria.

2.2. Field procedures

2.2.1. Collection of the fish hosts

Fifty specimens of each of both *S. clarias* and *C. nigrodigitatus* were freshly obtained from the study area. They were randomly purchased at the landing sites of fishermen in Epe, Lagos, Nigeria.

The fish specimens of *S. clarias* and *C. nigrodigitatus* were identified and measured.

A gross examination of the gonad was used for sex and maturity assessment to differentiate the males from females and to determine the immature ones. Measurement of the lengths of the fishes were done with the aid of a measuring board. Weights were determined by a weighing balance (Camry, EK5055) measuring to the nearest of 0.01 g. The gonads’ weight was also determined for the calculation of gonadosomatic index. The fishes were dissected and the gastrointestinal part of each fish was removed. This was examined inside by Petri dishes with physiological saline. They were carefully teased open to allow for the emergence of the parasites. Each worm was detected by its noticeable movement in the saline solution. Some of the worms could not, however, emerge being permanently attached to the gut walls of the gastrointestinal mucosa of their hosts. They were carefully removed with the aid of forceps. The helminth parasites from each fish were counted and preserved in 70% alcohol in different specimen bottles.

2.2.2. Processing of intestine for histopathology

Both infected and uninfected intestines were placed in separate bottles containing Bouin’s fluid. The Bouin’s fluid was decanted after 6 h while 10% phosphate buffered formalin was added

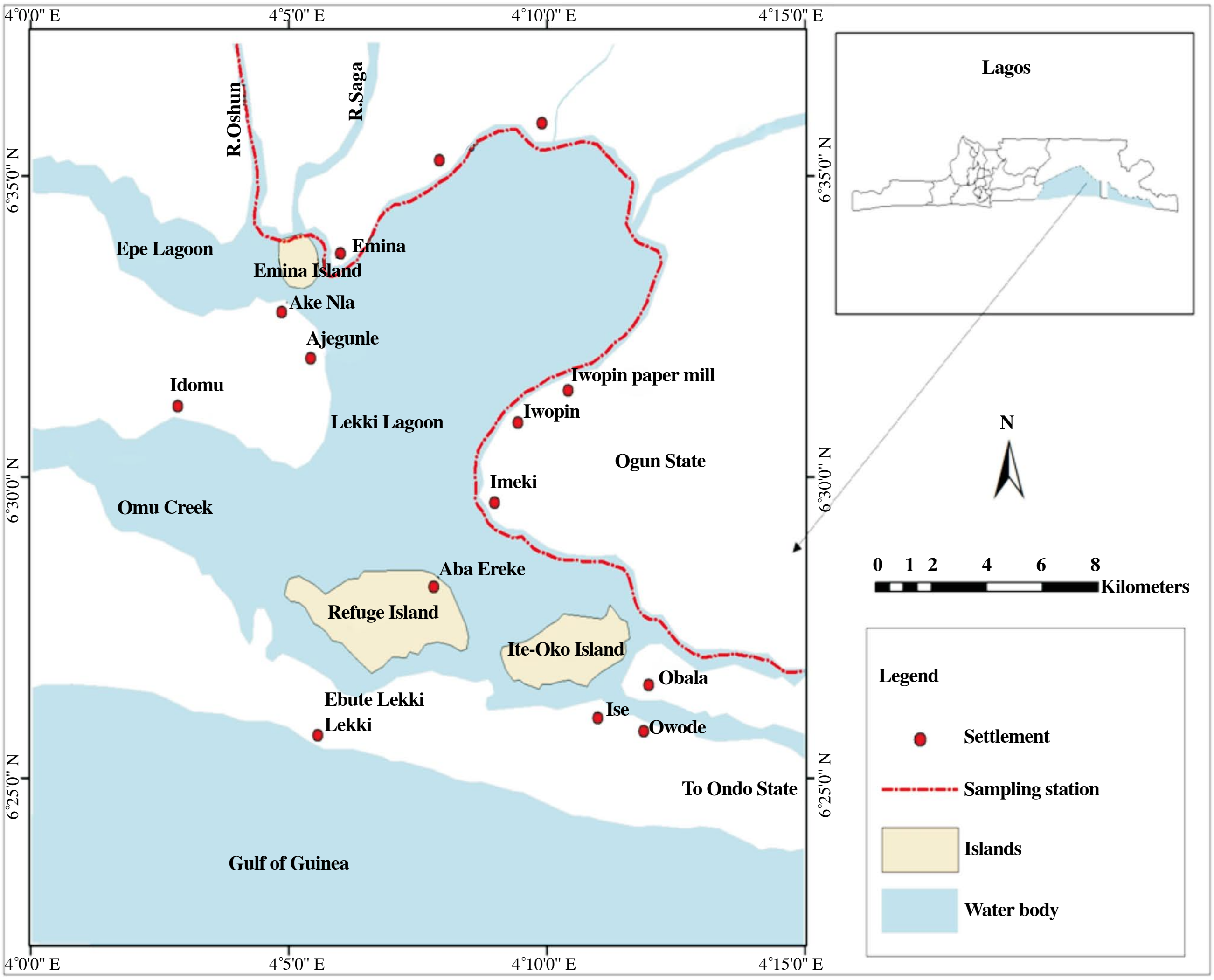

Figure 1. Map of the study area.

to preserve the tissues. Random selection was made from the preserved tissues while uninfected tissues were also chosen as the control. The dehydration of the tissues was carried out in increasing concentrations of alcohol and twice in absolute alcohol at 30 min interval. Impregnation of the tissues took place in molten paraffin three times and was later embedded in the wax and allowed to solidify. Sectioning of the tissues were carried out at 4–5 µm. A precoated slides was used to float the tissues and allowed to dry. Staining of the sections was done with the aid of haematoxylin-eosin stains. Tap water was used to wash off the stained tissues while the over stained ones were destained in 1% acid alcohol. DPX mountant was used to mount the tissues while they were examined under the microscope.

2.2.3. Heavy metal and stomach content analysis

In the heavy metals analysis, 3 g of the intestinal tissues of *S. clarias* and *C. nigrodigitatus* samples were digested with nitric acid (10 mL). The samples were then heated until brown fumes disappear. The samples were allowed to cool and distilled water was added to make up to 50 mL in a standard calibrated flask. The filtrate was examined by the atomic absorption spectrometer to determine trace metals impurities in the samples. The stomach of the fishes were carefully removed and examined inside a Petri dish with few drops of water. The stomach content of each fish was observed under the binocular microscope and the various food items were identified and recorded for each dissected fish. Fullness of the stomach of each specimen was recorded as 0/4, 1/4, 2/4, 3/4 and 4/4, representing empty stomach, quarter full stomach, half full stomach, respectively. For food analysis, the frequency of occurrence and numerical method were used.

3. Results

3.1. Prevalence of intestinal helminth parasites in both S. clarias and C. nigrodigitatus

The overall infections of the fish hosts were only observed in the gastrointestinal mucosa. In *S. clarias*, 12 specimens were infected (24.0%) and 38 (76.0%) were not infected. The infected individuals included 9 males (18.0%) and 3 females (6.0%) while the non-infected individuals had 26 males (52.0%) and 12 females (24.0%). In *C. nigrodigitatus*, 9 specimens were infected (18.0%) and 41 (82.0%) were not infected. The infected individuals had 6 males (12.0%) and 3 females (6.0%) while the non-infected individuals had 24 males (48.0%) and 17 females (34.0%). The *Chi*-square distributions were significant at 0.01 level [(χ^2 = 2.08, P < 0.01) and (χ^2 = 2.16, P < 0.01)], respectively.

3.2. Histopathological consequences of the fish hosts

The results of the infected tissues examined revealed different pathological consequences in the fish hosts such as severe degeneration of mucosal epithelium and unremarkable villi. The pathological conditions in the fish hosts were revealed in Figures 2 and 3.

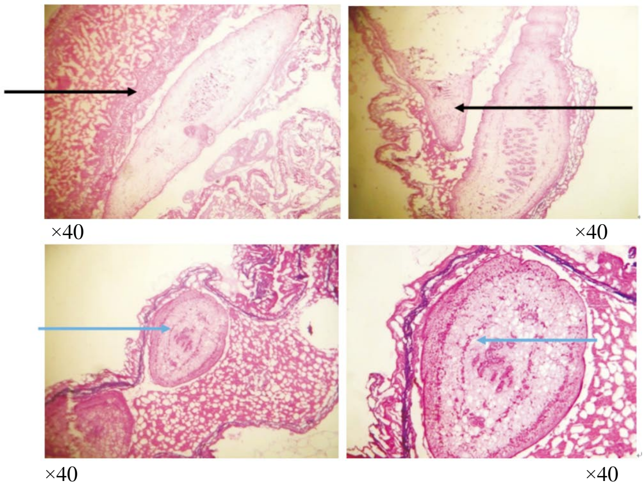

Figure 2. Sections of the intestine.
Black arrow: Numerous trophozoites (adult) of parasites (looks like a fluke); Blue arrow: Ova embedded within the lumen. Thin arrow: Severe degeneration of mucosal epithelium.

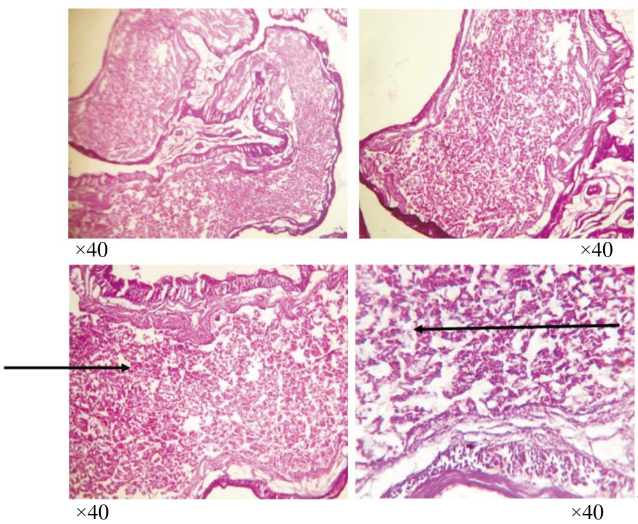

Figure 3. Sections of the intestine.
Black arrow: Severe degeneration of the mucosal epithelium. The villi were unremarkable. No parasites were seen.

3.3. Morphometry of C. nigrodigitatus and S. clarias in Lekki Lagoon

Randomly-selected specimens were measured to obtain their length and weight parameters. The total length of *C. nigrodigitatus* in females and males were (15.05 ± 3.27) cm and (20.85 ± 4.20) cm ($P < 0.01$), respectively. Also the total length of *S. clarias* in females and males were (21.07 ± 2.80) cm and (20.76 ± 2.37) cm ($P < 0.01$), respectively. The results of the morphometry and condition factors of the fish hosts were shown in Table 1.

3.4. Metal concentrations in fish intestine of S. clarias and C. nigrodigitatus and the parasites

Bioaccumulation of metals in the tissues of the fish hosts is a confirmation that can be used in which there is metal pollution and contamination in the water body. The ANOVA of the trace elements in the water and the intestinal walls of *S. clarias* and *C. nigrodigitatus* showed that the metal concentrations were significantly impactful and the aquatic ecosystem was polluted.

In infected specimens of *S. clarias,* the metal concentrations ranged from Zn > Mn > Fe > Pb > Cd and were Mn > Fe > Pb > Zn > Cd in the parasites (*Procamallanus* spp.). In infected *C. nigrodigitatus,* the metal concentrations ranged from Mn > Zn > Fe > Pb > Cd and were Zn > Mn > Fe > Pb > Cd in the parasites (*Siphodera* spp.). Cadmium was the lowest in both species.

The *Procamallanus* spp. of *S. clarias* was a good bioaccumulator as compared to the *Siphodera* spp. of *C. nigrodigitatatus*. The results of the metal concentrations were shown in Table 2.

3.5. Bioaccumulation factor of fishes and parasites in Lekki Lagoon

The bioaccumulation factors for *S. clarias* were higher in the non-infected fishes than the infected ones also in *C. nigrodigitatus*. In *S. clarias* parasites, the bioaccumulation factors were higher in two metals, Pb (23.167) and Fe (1.371), as compared to those of the infected intestines, but in *C. nigrodigitatus*, the bioaccumulation factors of Fe (3.034) was higher in the parasites as compared with those of the infected intestines, while other metals were higher in the infected intestines of the parasites (Table 3).

Table 1
Morphometry, condition factor and stomach content analysis of *S. clarias* and *C. nigrodigitatus* in Lekki Lagoon.

Fish	Sex	Total length (cm)	Standard length (cm)	Weight (kg)	Condition factor K	Stomach content
S. clarias	Male	20.76 ± 2.37	14.81 ± 1.12	79.95 ± 15.09	2.49 ± 0.53	0.65 ± 0.10
	Female	21.07 ± 2.80**	14.83 ± 1.56	91.67 ± 24.31**	2.82 ± 0.63	0.95 ± 0.20
C. nigrodigitatus	Male	20.85 ± 4.20**	16.03 ± 3.06**	72.97 ± 31.14**	1.73 ± 0.36**	0.75 ± 0.20
	Female	15.05 ± 3.27**	19.56 ± 4.42**	62.64 ± 31.22**	1.88 ± 0.92**	0.60 ± 0.10**

P value significant at *- 0.05 level.

Table 2
Heavy metals concentrations (mg/L) in fish intestines and parasitic organisms.

Fish	Tissue	No.	Pb	Fe	Zn	Cd	Mn
S. clarias	Infected intestine	10	0.06 ± 0.05	1.21 ± 1.15	5.61 ± 6.01	0.00 ± 0.00	3.61 ± 2.51
	Non-infected intestine	10	0.38 ± 0.54	1.81 ± 0.98*	4.52 ± 4.42	0.00 ± 0.00	4.84 ± 3.72*
	Procamallanus spp. (nematode)	3	1.39 ± 0.12*	1.66 ± 1.05	0.73 ± 0.93	0.03 ± 0.01*	1.95 ± 1.09
C. nigrodigitatus	Infected intestine	10	1.00 ± 1.12	2.01 ± 0.08*	3.02 ± 3.22	0.00 ± 0.00	5.04 ± 4.22
	Non-infected intestine	10	0.07 ± 0.12	1.18 ± 0.98*	4.52 ± 4.42	0.00 ± 0.00	4.84 ± 3.72
	Siphodera spp. (trematode)	3	0.02 ± 0.01	0.61 ± 0.59	3.61 ± 2.95	0.00 ± 0.00	2.01 ± 2.05

P value significant at * - 0.05 level, ** - 0.01 level.

Table 3
Bioaccumulation factor (BAF) of fishes (in relation to water) and parasites (in relation to infected hosts) in Lekki Lagoon. mg/kg.

Metals		Pb	Fe	Zn	Cd	Mn
Infected	*S. clarias*	7.416	1.113	5.332	0.000	3.909
	C. nigrodigitatus	1.236	1.850	2.870	0.000	5.457
Non- infected	*S. clarias*	4.697	1.666	4.296	0.000	5.240
	C. nigrodigitatus	8.652	1.086	4.296	0.000	5.240
Parasite	*Procamallanus longus*	23.167	1.371	1.301	0.000	5.401
	Siphodera ghanensis	0.020	3.034	1.195	0.000	3.988

3.6. Metal concentrations in water and sediment media of Lekki Lagoon

In Table 4, the metal concentrations in the water were higher as compared with those of the sediment and Cd was not detected in the sediment. The Federal Ministry of Environment limit indicated that the trace metals in the aquatic habitat and sediment were lower to the required limit.

Table 4
Concentrations of trace metals (mg/kg) in the aquatic habitat of Lekki Lagoon.

Medium	Pb	Fe	Zn	Cd	Mn
Water	0.809 ± 0.287	10.864 ± 1.721	1.052 ± 0.061	0.069 ± 0.015	9.235 ± 1.475
Sediment	0.911 ± 0.147	10.597 ± 0.933	0.071 ± 0.024	ND	8.878 ± 1.129
FME limit	Less than 1	20	Less than 1	Less than 1	NA

FME: Federal Ministry of Environment; ND: Not detected; NA: Not available.

4. Discussion

Parasites are ubiquitous and are capable of infecting every living organism. The presence of parasites in their host is at equilibrium in aquatic organisms with their evasive lifestyle on the planet[16]. In case of adverse stress predisposing factors, parasites attack their hosts and parasitic diseases can be transmitted from one host to another with grave consequences. So, the presence of parasitic infections in fishes is an indicator of environmental stress[17]. There is host-related reactions against the parasites which could lead to inflammatory lesions[5,11].

Helminthes parasite infections were higher in males in both *S. clarias* (18.0%) and *C. nigrodigitatus* (12.0%), respectively. Similar results that a higher rate of internal parasite infection was obtained in male fishes have been reported[18,19]. Higher prevalence in both genders of the fish hosts may be naturally enhanced. There is no scientific reason to link parasitic infections to a particular sex in the fish hosts. A study on *Synodontis eupterus*, *S. clarias*, *C. nigrodigitatus* and *Clarias kingsleye* shows that there is no specific trend in parasite prevalence in relation to weight classes[20].

The overall prevalence of the helminth parasites (18.0%) recorded in this study among *S. clarias* was lower than that of 85.2% reported in Zaria for *Synodontis* species[21]. The differences in the prevalences may be due to different conditions in the affected water bodies. Wang[15] has earlier reported that there is variation in parasitism from one aquatic ecosystem to the other and that this is as a result of interplay and mixed biotic and abiotic factors. A nematode of the family Camallanidae (*Procamallanus* spp.) was found in *S. clarias* and a trematode (*Siphodera ghanensis*) was also recovered in *C. nigrodigitatus*. Histopathological observations in the intestinal mucosa of the fish hosts shows different pathological effects. The research on pathological changes observed on visceral organs of some fishes reported various pathological conditions in the examined fishes[22]. In this study, several pathological conditions of the intestinal mucosa were also reported. Considerable spleen enlargement was observed with the increased parasite load in the pathology of European eel, *Anguilla anguilla,* by *Anguillicoloides crassus* as reported by Neto *et al.*[23]. Condition factor is also needed to assess the degree of the wellbeing of a fish population[24]. In this study, randomly-selected specimens were measured to obtain their length and weight parameters. The length strongly correlated with the weight between sexes and were all significant at 0.01 level. There were stronger correlations among the males as compared to the females in all the models used.

The regression exponent ($b < 3$) for both sexes of *S. clarias* (female: 0.752 and male: 0.538) and *C. nigrodigitatus* (female: 0.859 and male: 0.927) indicates a negative allometric growth pattern, which means the fish weight increases with the evident increase in length[25], while a positive allometric growth pattern was reported in *Amblypharyngodon mola* from the Mathabhanga river, Bangladesh[26]. Similar findings were made by Abowei and Davies[27] and Deekae *et al.*[28] where a negative allometric growth was obtained ($b = 0.88$ and $b = 2.88$) for the studies of *Clarotes laticeps*.

The relationship between length and weight of fish is anchored on factors such as season, habitat, gonad maturity, sex, diet and annual fluctuations in environmental conditions[11]. The differences in reports could be attributed to or combined factors of the differences in the number of species, sizes of species, geographical location and season[22].

The general wellbeing of fishes is an estimation of its condition factor[1]. It is anchored on the fact that fishes with high weight in a given length are in better condition than fishes with less weight[11]. The determination of the general wellbeing of a fish is an index of its growth and feeding intensity. Marcogliese[1] reported that the wellbeing of fishes in different populations who are of the same species is a confirmation of the availability of food supply and regular timing and duration of breeding. Dyková and Lom[29] reported that the extent of the wellbeing of a fish can be influenced by factors such as sex, age, season, maturity and food preference of the organism. The condition factors in this study were (1.88 ± 0.92) for females and (1.73 ± 0.36) for males in *C. nigrodigitatus* and (2.82 ± 0.63) for females and (2.49 ± 0.53) for males in *S. clarias*. The mean value for the condition factor of both *S. clarias* and *C. nigrodigitatus* were > 2.0. The condition factor as reported in this study is to determine the wellbeing of the fish hosts as a result of the stressed based on the uptake of the contaminants in the aquatic ecosystem as reported for mature fresh water fish body weight[30]. This suggested that the water body might be favorable for *S. clarias* and *C. nigrodigitatus* species.

Information on the trace elements in the aquatic habitat and in the fauna is important since this reveals the extent of pollution in the different portions of the water body and the degree of accumulation[31].

Contamination of aquatic system by heavy metals has attracted the attention of several researchers all over the world. Wastes from industries and agricultural processes have contributed to the pollution of aquatic ecosystems leading to several pathological conditions on the aquatic biota and human health[15]. It is of interest to note that these trace elements can accumulate in the tissues of aquatic animals which then should be a concern to humans because of their deleterious effects[21,32]. Metals are reported to be well concentrated in the water, sediments and biota[5]. Some parasites may be susceptible to metals accumulation[6]. It has been reported that cestodes have the ability to accumulate metals far above the levels found in their host tissues[6]. Monogeneans parasites being in direct contact with the environment are vulnerable to trace metals accumulation[4]. Bush *et al.*[8] stated that parasites prefer to remain and camouflage in their hosts so as to evade immune assault as a survival strategy. The reports of Karthikeyan *et al.*[33] have proved the ability of fishes to accumulate and retain trace elements in their tissues with the degree of which is depending upon the magnitude of the contaminants, duration, salinity, temperature and metabolic activities of the animals.

Accumulation of contaminants in tissues of aquatic organisms has been reported to be an indirect measure of determining the abundance of the environment[34]. This then serves as the early detection of aquatic contamination[16].

The bioaccumulation factors for *S. clarias* were higher in the non-infected than the infected while in *C. nigrodigitatus* the bioaccumulation factors were higher in the infected than the non-infected. In *S. clarias* parasites, the bioaccumulation factors were higher in three metals, Pb (7.416), Zn (5.332) and Mn (3.909) as compared to that of the non-infected intestines, but in *C. nigrodigitatus*, the bioaccumulation factors were still higher in the infected intestines as compared to the parasites. Saliu *et al.*[35] reported high metal accumulation in *Tilapia guineensis* from Iddo area of Lagos State. This is also in conformity with the present results. Thielen *et al.*[36] using the intestinal parasites *Pomphorhynchus laevis* from barbel as a bioindicator for metal pollution reported that ten of the twenty one elements analyzed were found in the Acanthocephala. Heavy metal bioaccumulation factors in infected hosts' tissues were lower than in the helminth parasites of *S. clarias* in three metals (Pb, Fe and Mn) and *C. nigrodigitatus* (Pb, Zn and Cd), and lower in the parasites than the infected intestines. This confirmed that guts of the parasites of the fishes are poor accumulator indicators of heavy metals due to the low levels of metal concentrations[37].

Iron (Fe) was found to be the most abundant metal in Lagos Lagoon (10.864 ± 1.721) and (10.597 ± 0.933), respectively. This is expected because iron occurs at high level in Nigeria soil as reported by Nwajei and Gagophien[38].

The results from this study indicate that the heavy metals recovered are Mn, Fe and Zn. Mn and Zn are essential elements. Mn is contained in batteries, fertilizers, varnish, fungicides and livestock feeding supplements. The metal is capable of bioaccumulation in phytoplankton, algae, molluscs and fishes. Heart diseases in man have been linked to Mn toxicity[39]. Excess of Zn in man may be detrimental leading to some pathological effects. The metal can be found in alloys, batteries, fungicides and pigments[39]. The results of the metal concentrations in the water and sediments were below the Federal Ministry of Environment permissible limit, which is a confirmation that the fishes in the lagoon can still be consumed by man without any deleterious effects. Parasites are reported to cause serious pathological consequences on the hosts together with their ability to bioaccumulate contaminants[22]. Heavy metals are common in the surface sediments of aquatic ecosystems[40]. Histopathological consequences of protozoan parasites on their hosts are also highly pronounced[29]. It should be noted that metals are better characterized in both water and sediments where a particular host has been examined. Some marine animals were examined for heavy metals accumulation in their tissues in some researches[41,42]. The systemic pathology of the fish hosts in relation to diseases should be thoroughly examined[22,43]. Parasitic worms of fishes are good for monitoring the environment[44-47], while World Health Organisation[48] emphasized that guidelines for good water quality should be strictly adhered to. Generally, heavy metals are higher in the livers and gills than in the muscles of fishes as reported in a research during the analysis of contaminants in two fish species from the southwestern Mediterranean coast of Sfax[49]. Digeneans and other helminthes parasites are important and have been tested as potential bioindicators to monitor environmental pollution for both freshwater and marine ecosystems[48,49]. Constant monitoring is, therefore, advised to detect any increase in the magnitude of the contaminants.

Conflict of interest statement

We declare that we have no conflict of interest.

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