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FISH PARASITES IN DIFFERING WATER QUALITIES AND THE HEALTH RISK ASSESSMENT OF FISH CONSUMPTION IN COASTAL COMMUNITIES OF CALABAR, NIGERIA.

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Abstract

The study was aimed at determining the parasites of fish in differing water qualities, as well as the health risk assessment of fish consumption in coastal communities in Calabar, Nigeria. Two water bodies: Calabar River and Great Kwa River were chosen for the study. All the fish species caught were screened for parasites and subjected to tissue analysis for heavy metal concentrations using established protocols. The study shows that *Coptodon zillii*, *Coptodon guineensis, Chrysichthys auratus, Clarias gariepinus* and *Mugil cephalus* were infected with helminth and has prevalence of 15.00%, 11.00%, 14.00%, 17.00% and 10.00% respectively. This study shows that there was no significant different across the two sites at the $P \leq 0.05$ ($\propto = 0.05$). The prevalence (11.21 %, 11.41% and 11,53%) of infection of small weight (< 300g) fish increases with increase in weight (0-99g,100-199g and 200-299g) in Calabar River but did not so in Great Kwa River. The mean intensities of fish infections of small weight (<300g) are the same while for large weight (above 300g) is higher. Four species of Monogenean, 3 species of Cestodes, 4 species of Trematodes (Digenean), 5 species of Nematodes and 2 species of acanthocephalans were recovered. Heavy metals (Cadmium, Zinc, Lead, Nickel, and Copper) concentration of non-infected was significantly (P-0.05) different from infected fish tissues of both rivers at p-value of 0.001 and 0.001 respectively. The BAF, THQ and Hi of fish tissues is less than 1. We recommend more tissues should be analysed and fish be cook properly before consumption.

Keywords: Parasites, Bioaccumulation, Heavy metals, Total Hazard Quotient and Hazard Index.

1.0 introduction

Parasites are pervasive in ecological systems, with the potential to infect a wide range of free-living organisms, as highlighted by Madanire-Moyo and Barson (2010). Parasites can cause mechanical damage in fish such as fusion of gill lamellae, tissue replacement or, physiological damage (cell proliferation, immunomodulation, detrimental behavioural responses, altered growth) and reproductive damage. It is believed by many that parasites are only as important as the fish they infect. Changes in the environment, both anthropogenic and abiotic, can alter the parasite/host equilibrium and cause disease or mortality in fish. And usually, the damage to the fish is relative to the rate of parasitic infection; a fish that is lightly infected will show few signs, while a heavily infected fish may become physiologically impaired and even die (Deborah, 2014). Parasitic infections from freshwater fish are a serious problem in some parts of the world.

Fish is a predominant meal at all levels in almost all homes across the world. The fisheries sector contributes immensely to the nutritional security and food to about 200 million Africans and it also generates income for over 10 million others engaged in fish production, processing and trade (Kevin *et al*., 2019). But the role of freshwater fish in transmitting parasites to humans had been known for a long time. Fish parasites and diseases remain some of the most important problems confronting the fishery Biologist (Solomon *et al*., 2019). Fish serves as hosts to parasites, making them crucial in understanding parasitic diseases' direct and indirect impacts on wild fish populations.

A major problem of aquatic life is the level of pollution that occur in the water environment. In aquatic environment most contaminants (pollutants) tend to accumulate in organisms, in which they can reach levels hundreds or thousand times higher than the relevant water levels. Fish constitute a major source of heavy metals in food (Sivakumar and Xiaoyu, 2018). High level of metals in the environment may lead to an excessive accumulation which cause problem to human, animal and plants (Hazrat *et al*., 2019). Fish, acting as biological indicators, often concentrate pollutants, including metals, at levels significantly higher than those found in the surrounding water (Osama *et al*., 2022). Fish parasites, existing in balance with their hosts in natural settings (Öktener and Bănăduc, 2023), play a dual role as indicators of environmental pollution and potential reducers of metal bioaccumulation in fish tissues. In freshwater habitats fish intestinal parasites can accumulate heavy metals at concentrations orders of magnitude higher than the tissues of their fish hosts, and so potentially provide useful information about the chemical condition of the environment. Therefore, using the parasites of fish as biological indicators to determine the pollution level and not the usual ecological assessment as usual is essential.

Fish parasites can be utilized as biological indicators for metal pollution. They exhibit a higher rate of heavy metal accumulation in their tissues compared to fish tissues, establishing them as potential metal bio-sinks or sentinels in aquatic habitats (Osama *et al*., 2022). This dual role positions fish parasites as valuable tools for monitoring environmental and human health risk assessment and understanding the intricate dynamics between contaminants, hosts, and the broader ecosystem

2.0 Methods and Materials

2.1 Study Area

The study was carried out in two selected water bodies, namely, the Calabar River and the Great Kwa River. The Calabar River takes its rise from the Oban Hills in Akamkpa, Cross River State, Nigeria and flows southwards. The Great Kwa River is one of the major tributaries of the Cross River Basin. It takes its course from the Oban Hills in Aningeje, Cross River State, Nigeria and flows southwards before discharging into the Cross-River Estuary around latitude 4°45'N and longitudes 8°20'E (Akpan, 2000). *Less than half of the population of Calabar City is found along the Calabar River coast and carry out economic activities in the area (*Simon, 2010). *T*he city is bounded by the Calabar River to the west, Great Kwa River to the east and the wetlands (Creeks) of the Cross-River Estuary to the South. It can only grow to the north, into the Calabar River and Great Kwa River catchment areas. The Calabar river watershed was originally covered by tropical rainforest which has now been replaced by agriculture, road construction, forestry, industry and housing for the growing population of Calabar.

2.2 Fish Sample Collection and Examination

Different fish species were collected from four different stations on their landing points namely; Nsidung Beach (for Calabar River) and Atimbo Beach (for the Great Kwa River), Fishermen who normally fished from these water bodies, were engaged to catch weekly for 40 weeks and deliver same. Freshly collected fish were immediately kept in plastic containers (coolers) with ice blocks for preservation and to arrest decomposition, and immediately transported to the Biology Laboratory, University of Cross River State (UNICROSS).

Fish collected early in the morning were immediately taken to the laboratory and examined same day. Fish samples were examined externally before dissection. All procedures followed that of Marcogliese, (2001). Total and standard lengths of each fish sample were measured using a measuring tape. The fish samples were also weighed to the nearest gram using Ohrus Electronic Weighing Balance; Model CS 20000 REV.005.

2.2.1 Fulton Condition's Factor

The Fulton's condition factor which represents species richness and robustness was determined. This was calculated using the formula

$K = Wx100 / L^3$

Where W= the weight of Fish

L= the length in cubes

2.2.2 Heavy Metal Analysis

Fish parts to be analysed were washed with deionized water and deep frozen as described by Abdulali *et al*. (2012) while awaiting analysis. The frozen boneless tissues (liver, gills and muscles) of the fish were thawed for heavy metal analysis as stated by Bawuro *et al*. (2018). The organs (liver, gills and muscles) were homogenized and weighed and dried to a constant weight at 80°C for two days in acid-washed petri dishes. When at constant weight, the samples were allowed to cool in the desiccators and crushed into a fine powder by using a porcelain mortar and pestle. A duplicate of 0.5 g dry-weight (DW) of powdered muscle and gill respectively, and 0.1 g dry-weight (DW) of powdered liver (liver being relatively tiny compared to the gills and muscles) were used. Samples were digested using closed vessel microwave digestion in a microwave oven (Milestone model Start D, Italy), and ultra-pure nitric acid (65%) and hydrogen peroxide (35%) mixture in 3:1 ratio at a temperature of 150°C for 20 minutes, following a cooling to room temperature for 35 min in the microwave (Taghipour and Aziz, 2010; Taweel *et al*., 2011). Hydrogen peroxide was added to the samples with nitric acid as it decreases nitrous vapors and speeds up the digestion of organic substances by elevating the reaction temperature (Dig-Acids, 2001). The microwave digestion method is an accurate method for samples digestion compared with others methods such as dry washing and wet digestion (Mendil *et al.*, 2010). The digested samples would be diluted with deionized water to a total volume of 25 mL for liver and 50 mL for gills and muscles, then filtering through 0.45 µm Whatman filter paper. The analysis was performed by inductively-coupled plasma mass spectrometry (ICP-MS) (model ELAN 9000 Perkin Elmer ICP-MS, USA) assessing for the concentrations of five heavy metals namely, cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni) and copper (Cu), expressed as mg/kg dry weight (DW). It must be pointed out that all the glassware and plastics were soaked overnight in 10% (v/v) nitric acid and rinsed with distilled and deionized water and dried before use (Khansari *et al.*, 2005).

2.2.3 Health Risk Assessment Analysis

i. Using Bioaccumulation Factor (BAF) which is the ratio between the concentration of the analyzed metal in an organism and the concentration of the same metal in water, during steady state. Analysis using BAF

BAF= Ct/Cw

where Ct was the metal concentration in the fish tissues, Cw was the metal concentration in water (Xiaoxun, 2019)

ii. The THQ describes the non-carcinogenic health risk posed by exposure to the respective toxic element. If the THQ is <1 then non-carcinogenic health effects are not expected. If, however, the THQ is >1 then there is a possibility that adverse health effects could be experienced. and

THQ

THQ = EDI/RfD

$EDI = Conc_{tissue} \times Ing\ R_{tissue} \times F \times RAF \times EF \times ED \times CF/AT \times BW$

Where:

EDI = Estimated daily intake (mg/Kg/day)

$Conc_{tissue}$: Concentration of metals in tissue (mg/Kg)

$IngR_{tissue}$ = Ingestion rate for fish tissue (291.7 g/day for adults) (Yee, 2010)

F = Fraction of contaminant absorbed from site (1: 100% of contaminant assumed to be available from the site).

RAF = Relative absorption factor (1: for both toddlers and adult).

EF = Exposure frequency (365 days/year)

ED = Exposure duration (69.79 years for adults)

CF = Conversion factor (1.0×10^{-3} Kg/g)

AT = Averaging time (29200 for adults; exposure frequency multiplied by exposure duration)

BW = Body weight (67.5Kg for adults) (Sasu, 2023)

While RfD is the reference dose (µg/kg day-1) {For Lead (Pb) = 0.004 mg/kg day-1, Zinc (Zn) = 0.3 mg/kg day-1, Cadmium (Cd) = 0.001 mg/kg day-1, Copper (Cu) = 0.04 mg/kg day-1 and Nickel (Ni) = 0.02 mg/kg day-1 (USEPA, 2018)

2.3 Data Analysis

Statistical analysis was performed using Statistical Product and Service Solution (SPSS) version 25. Results were presented using percentages and frequencies expressed in figures and chats. Variables were further analysed using f-distribution and t-test to test for the association between Fish hosts and prevalence of infection at 0.05 level of significance. In addition to this, Pearson correlation analysis was used to assess the relationship between the weight and length of fish and the prevalence of infection among these fish. Differences, associations and relationships were considered significant if $P < 0.05$. Terminology of infection statistics as defined by Bush *et al*. (1997) was also employed in the analysis of the data which includes.

1. **Prevalence -** is the proportion of those infection to the total examined
2. **Mean Intensity** – Is the average intensity of a particular species of parasite among the infected members of a particular host species. In other words, it is the total number of parasites of a particular species found in a sample divided by the number of hosts infected with that parasite.
3. **Abundance** – Is the number of individuals of a particular parasite in/on a single host regardless of whether or not the host is infected.
4. **Mean Abundance** – Is the total number of individuals of a particular parasite species in a sample of a particular host species divided by the total number of hosts of that species examined (including both infected and uninfected hosts).

3.0 Results

A total of 500 fishes made up of 5 species were caught in the two water bodies. Only 67 fish were infected with fish parasites which represent 13.4%.

3.1 Overall Prevalence and overall mean intensity of fish infections in the two water bodies

A total of 500 fishes made up of 5 species were caught in the two water bodies. Only 67 fish were infected with fish parasites which represent 13.4%. Clarias gariepinus was infected more than other and Mugil cephalus least infected among the five species observed as shown in table 1. The overall Mean intensity of infection is shows that the highest is 1.30 in *Mugil cephalus*, followed by 1.14 in *C. auratus* and the least is 1.09 in *C. gariepinus*.

Table 1 Overall prevalence and overall mean intensity of fish infections in the two water bodies

Fish Species	Total Number examined	Total number positive	Prevalence (%)	Total number of parasites counted	Mean intensity
Coptodon zillii (Red-belly tilapia)	100	15	15.00	17	1.13
Coptodon guineensis (Guinean tilapia)	100	11	11.00	12	1.09
Chrysichthys auratus	100	14	14.00	16	1.14
Clarias gariepinus	100	17	17.00	17	1.00
Mugil cephalus (Striped mullet)	100	10	10.00	13	1.30
Total	500	67	13.40	75	1.12

3.2. Prevalence and mean intensity of fish infections

3.2.1 Prevalence and mean intensity of fish infections from the Calabar River

Prevalence and Mean Intensity of helminths of fish species collected from Calabar River is presented in Table 2. A total of 250 fishes were caught from Calabar River. The highest prevalence among the fish species was

18.00% recorded in *Clarias gariepinus* and lowest (10.00) in *Mugil cephalus*. The highest Mean Intensity (1.40) was recorded in one species (*Mugil cephalus*) and lowest (1.00) in *Coptodon zillii*, *Coptodon guineensis* and *Clarias gariepinus.*

Table 2 Prevalence and Mean Intensity of helminths of fish species collected from Calabar River

Fish Species	Local/Efik Names	No. Exam	No. positive	Prev (%)	No. counted	Mean intensity
Coptodon zillii (Red-belly tilapia)	Okwe	50	8	16.00	8	1.00
Coptodon guineensis (Guinean tilapia)	Asat	50	6	12.00	6	1.00
Chrysichthys auratus	Inagha	50	8	16.00	9	1.13
Clarias gariepinus	Ofot	50	9	18.00	9	1.00
Mugil cephalus (Striped mullet)	Imin	50	5	10.00	7	1.40
Total		**250**	**36**	**14.40**	**39**	**1.08**

3.2.2 Prevalence and mean intensity of fish infections from the Great Kwa River

Prevalence and Mean Intensity of helminths of fish species collected from the Great Kwa River is presented in Table 3. A total of 250 fishes were caught from Great Kwa River. The highest prevalence among the fish species was 16.00% recorded in *Clarias gariepinus* and lowest (10.00) in *Mugil cephalus* and *Coptodon guineensis.* The highest Mean Intensity (1.29) was recorded in one species (*Coptodon zillii*) and lowest (1.00) in *Clarias gariepinus.*

Table 3 Prevalence and Mean Intensity of helminths of fish species collected from Great Kwa River

Fish Species	Local/Efik Names	No. Exam	No. positive	Prev (%)	No. counted	Mean intensity
Coptodon zillii (Red-belly tilapia)	Okwe	**50**	**7**	14.00	**9**	1.29
Coptodon guineensis (Guinean tilapia)	Asat	**50**	**5**	10.00	**6**	1.20
Chrysichthys auratus	Inagha	**50**	**6**	12.00	**7**	1.17
Clarias gariepinus	Ofot	**50**	**8**	16.00	**8**	1.00
Mugil cephalus (Striped mullet)	Imin	**50**	**5**	10.00	**6**	1.20
Total		**250**	**31**	**12.4**	**36**	**1.16**

3.3 Prevalence and mean intensity of fish infections in relation to weight of fish

The prevalence of fish infections in relation to weight of fish in both river is presented in two parts, namely: (i) the relatively small fish species with weight less than 300 g and (ii) the fish species with relatively larger weight (above 300 g). The prevalence of fish infections in relation to weight of fish for relatively small weight fish increases with increase in weight in Calabar River but did not follow any pattern in Great Kwa River. Larger weight of fish did not follow any trend in both River as shown in figure 2, 3, 4, and 5.

The mean intensities of fish infections in relation to weight of fish for relatively small weight seems to be the same in Calabar River but different in Great kwa River. while for large weight fishes as presented seems to be higher in in fish weight 400-499 from both Rivers as shown in Figures 6, 7, 8 and 9 respectively. Further details on prevalence and mean intensities of fish parasitic infections in relation to fish weight of various fish species is presented in table 4 and 5.

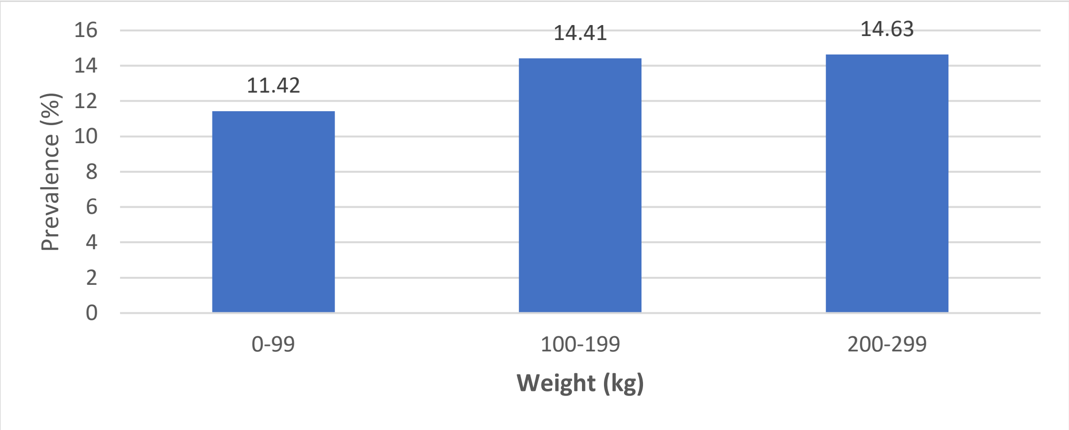

Figure 2. Prevalence of fish parasitic infections in relation to fish with weight ≥ 300 g Calabar River.

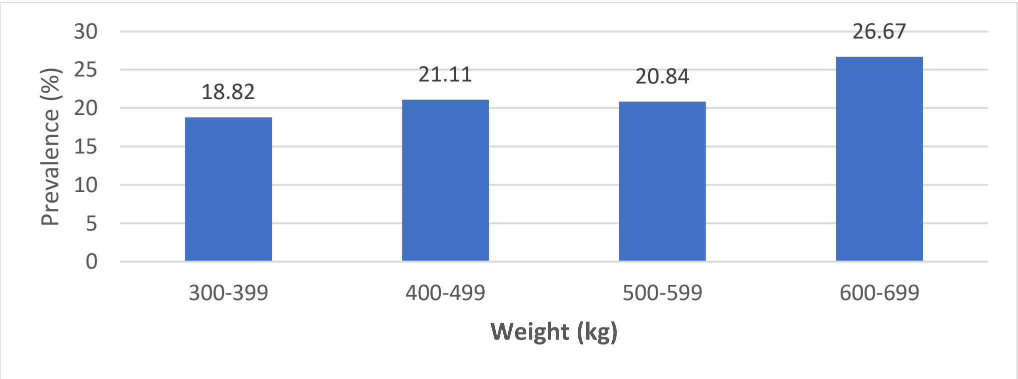

Figure 3. Prevalence of fish parasitic infections in relation to fish with weight ≥ 300 g Calabar River.

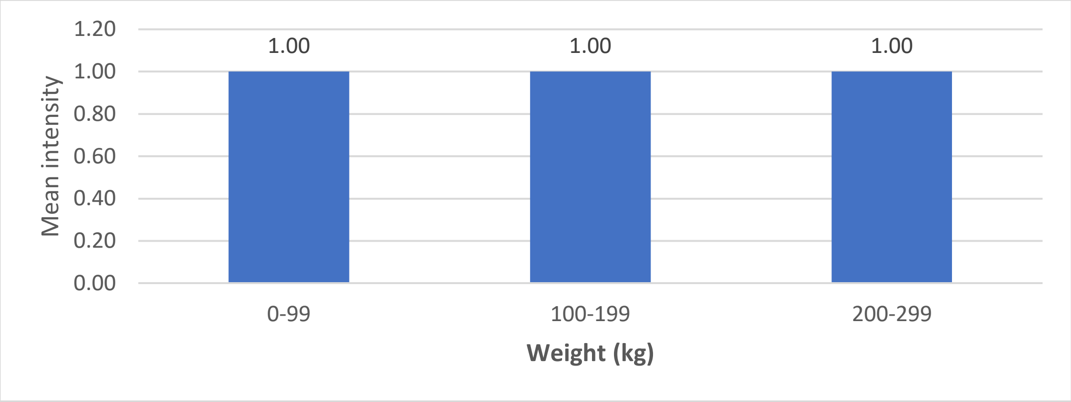

Figure 4. Mean intensities of fish parasites in relation to fish with weight ≤ 300 g Calabar River.

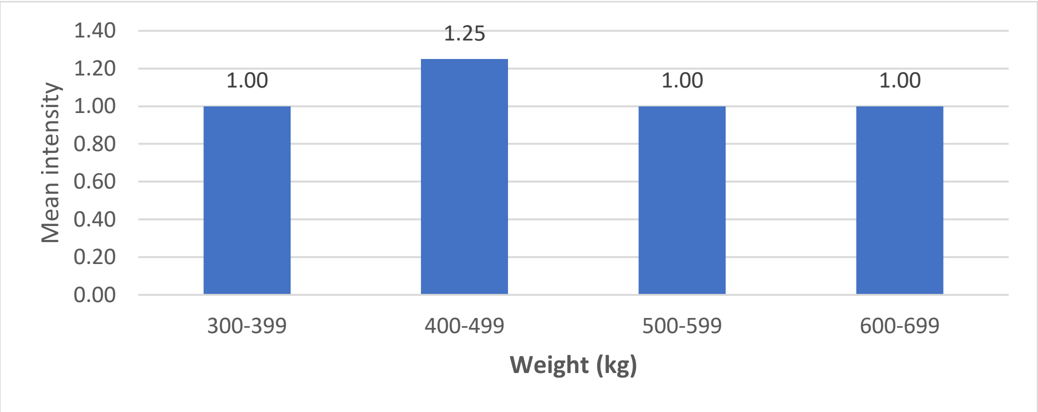

Figure 5. Mean intensities of fish parasites in relation to fish with weight ≥ 300 g Calabar River.

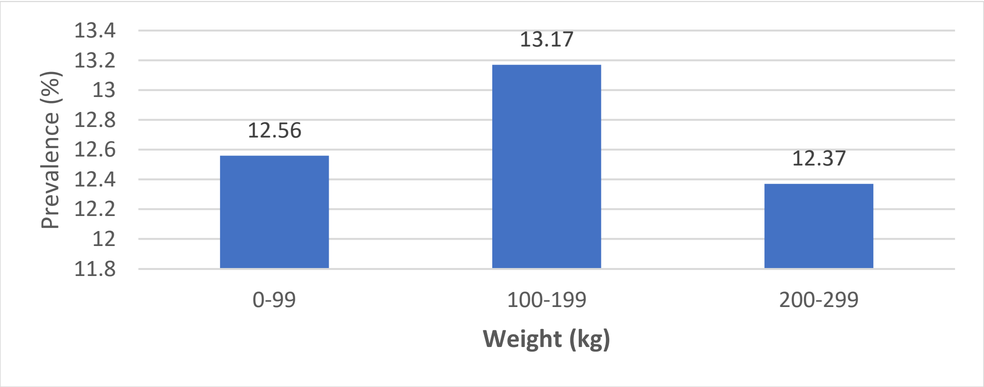

Figure 6. Prevalence of fish parasitic infections in relation to fish with weight ≤ 300 g Great Kwa River.

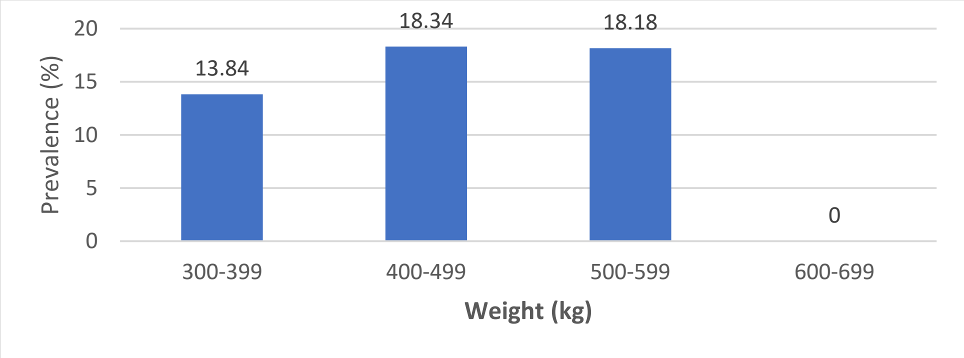

Figure 7. Prevalence of fish parasitic infections in relation to fish with weight ≥ 300 g Great Kwa River.

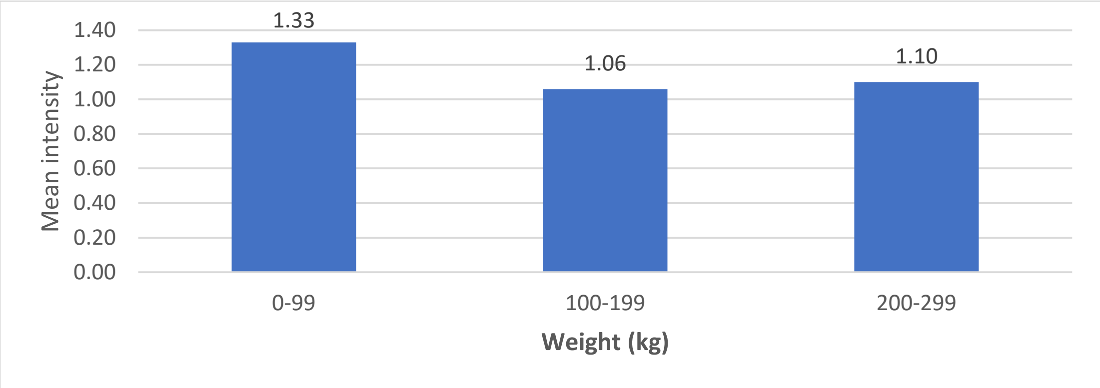

Figure 8. Mean intensities of fish parasites in relation to fish with weight ≤ 300 g Great Kwa River.

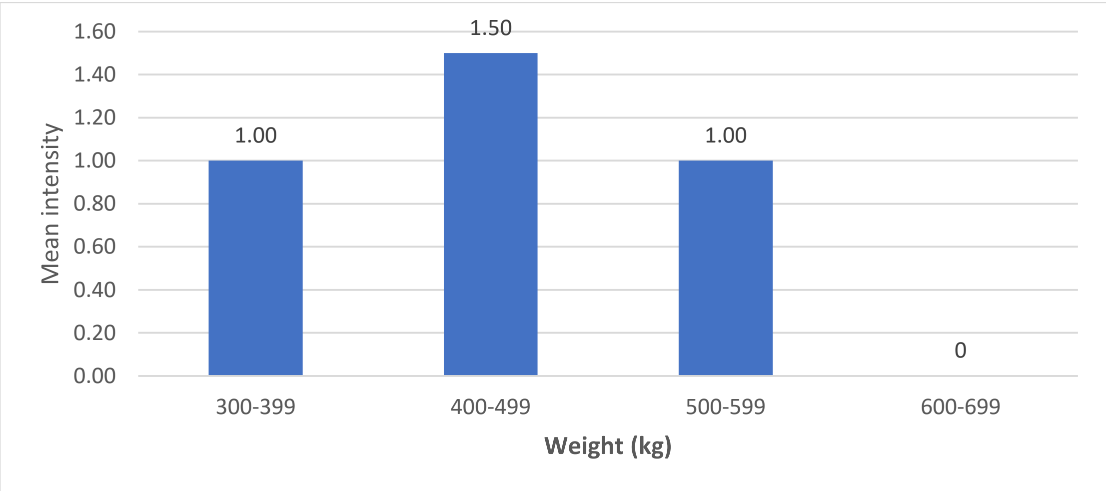

Figure 9. Mean intensities of fish parasites in relation to fish with weight ≥ 300 g Great Kwa River.

Table 4 Prevalence and Mean intensities of fish parasitic infections in relation to fish weight of various fish species in Calabar River

Fish Species	Fish weight(g)	Average weight (g) (~)	N. E	N.I.	P (%)	N. P. R	M. I. I
	0-99	78	**13**	**2**	15.38	**2**	**1.00**
Coptodon zillii (Red-belly tilapia)	100-199	150	**19**	**2**	10.53	**2**	**1.00**
	200-299	260	**18**	**4**	22.22	**4**	**1.00**
	0-99	76	**14**	**1**	7.14	**1**	**1.00**
Coptodon guineensis (Guinean tilapia)	100-199	155	**21**	**4**	19.05	**4**	**1.00**
	200-299	251	**15**	**1**	6.67	**1**	**1.00**
	0-99	-	**-**	**-**	-	**-**	**-**
	100-199	191	**7**	**1**	14.29	**1**	**1.00**
	200-299	279	**8**	**1**	12.50	**1**	**1.00**
Chrysichthys auratus	300-399	364	**10**	**2**	20.00	**2**	**1.00**
	400-499	470	**9**	**2**	22.22	**3**	**1.50**
	500-599	568	**6**	**1**	16.67	**1**	**1.00**
	600-699	681	**5**	**1**	20.00	**1**	**1.00**
	700-799	752	**5**	**-**	-	**-**	**-**
	0-99	-	**-**	**-**	-	**-**	**-**
	100-199	188	**6**	**1**	16.67	**1**	**1.00**
	200-299	278	**5**	**1**	20.00	**1**	**1.00**
	300-399	368	**17**	**3**	17.65	**3**	**1.00**
	400-499	459	**10**	**2**	20.00	**2**	**1.00**

Clarias	500-599	541	**4**	**1**	25.00	**1**	**1.00**
gariepinus	600-699	668	**3**	**1**	33.33	**1**	**1.00**
	700-799	781	**3**	**-**	-	**-**	**-**
	800-899	862	**2**	**-**	-	**-**	**-**
	0-99	77	**17**	**2**	11.76	**2**	**1.00**
Mugil	100-199	162	**16**	**2**	12.50	**2**	**1.00**
cephalus	200-299	256	**17**	**1**	11.76	**1**	**1.00**
(Striped mullet)							
Total			**250**	**36**		**39**	

Table 5. Prevalence and Mean intensities of fish parasitic infections in relation to fish weight of various fish species in Great kwa River

Fish Species	**Fish weight(g)**	**Average weight (g) (~)**	**N. E**	**N.I.**	**P (%)**	**N. P. R**	**M. I. I**
	0-99	72	**15**	**2**	13.33	**2**	**1.00**
Coptodon zillii	100-199	140	**18**	**3**	16.67	**4**	**1.33**
(Red-belly tilapia)	200-299	240	**17**	**2**	11.76	**3**	**1.50**
	0-99	79	**13**	**1**	7.69	**2**	**2.00**
Coptodon	100-199	155	**17**	**2**	11.76	**2**	**1.00**
guineensis	200-299	241	**20**	**2**	10.00	**2**	**1.00**
(Guinean tilapia)							
	0-99	85	**-**	**-**	-	**-**	**-**
	100-199	181	**7**	**1**	14.29	**1**	**1.00**
	200-299	270	**11**	**2**	16.67	**2**	**1.00**
Chrysichthys	300-399	350	**10**	**2**	20.00	**2**	**1.00**
auratus	400-499	460	**5**	**1**	20.00	**2**	**2.00**

	500-599	565	**7**	**-**	-	**-**	**-**
	600-699	680	**6**	**-**	-	**-**	**-**
	700-799	748	**4**	**-**	-	**-**	**-**
	0-99	87	**-**	**-**	-	**-**	**-**
	100-199	168	**8**	**1**	12.50	**1**	**1.00**
	200-299	275	**11**	**2**	18.18	**2**	**1.00**
	300-399	338	**13**	**1**	7.69	**1**	**1.00**
Clarias gariepinus	400-499	459	**12**	**2**	16.67	**2**	**1.00**
	500-599	540	**11**	**2**	18.18	**2**	**1.00**
	600-699	648	**6**	**-**	-	**-**	**-**
	700-799	730	**5**	**-**	-	**-**	**-**
	800-899	862	**4**	**-**	-	**-**	**-**
	0-99	72	**12**	**2**	16.67	**2**	**1.00**
Mugil cephalus	100-199	152	**19**	**2**	10.53	**2**	**1.00**
(Striped mullet)	200-299	236	**19**	**1**	5.26	**1**	**1.00**
Total			**250**	**31**		**36**	

3.4 Prevalence and mean intensity of fish infections in relation to Length of fish

The prevalence of fish infections in relation to length of fish in both river is presented in two parts, namely: (i) the relatively small fish species with length less than 25 cm and
(ii) the fish species with relatively larger weight (above 25 cm). The prevalence of fish infections in relation to length of fish for relatively small and large fish in Calabar and Great Kwa River increases with increase in length. The Mean intensity for relatively small fish length decrease with increase fish length while large fish length seems to be constant in Calabar River, but decreases with increase length in Great Kwa River as show in figure 10,11, 12, 13, 14, 15, 16 and 17. Further details on prevalence and mean intensities of fish parasitic infections in relation to fish weight of various fish species is presented in table 6 and 7.

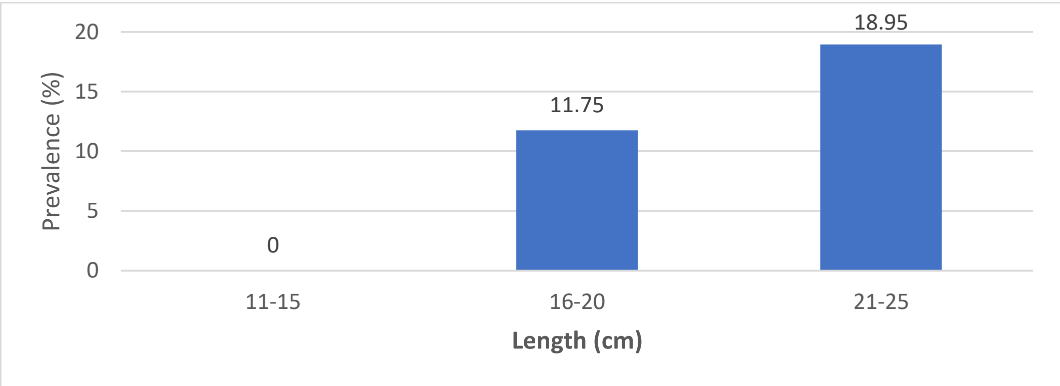

Figure 10. Prevalence of fish parasitic infections in relation to fish with length ≤ 25cm Calabar River

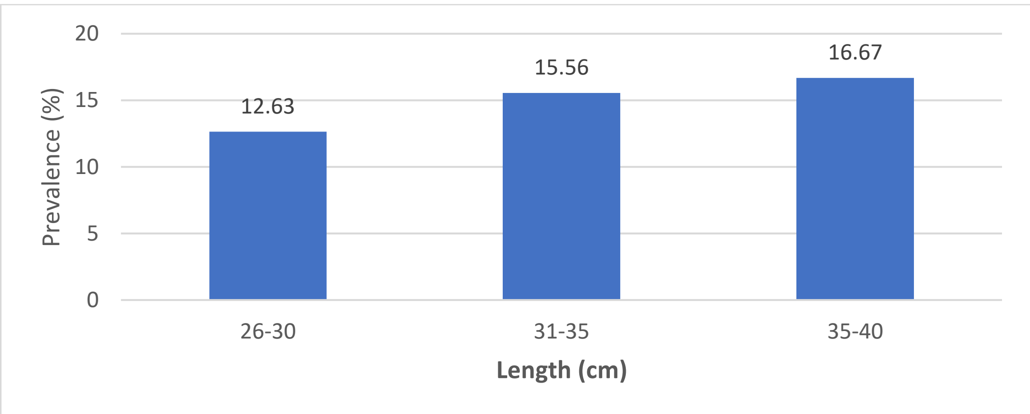

Figure 11. Prevalence of fish parasitic infections in relation to fish with length ≥ 25cm Calabar River

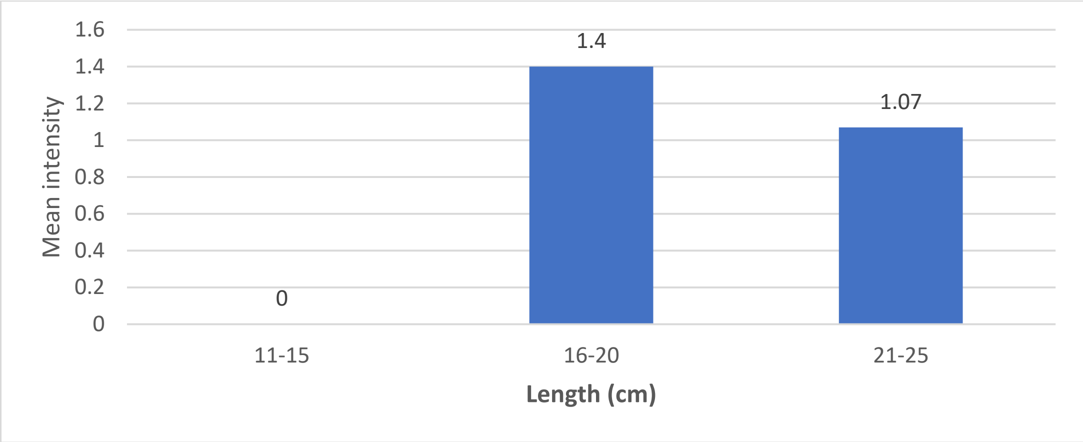

Figure 12. Mean intensities of fish parasites in relation to fish with length ≤ 25cm Calabar River

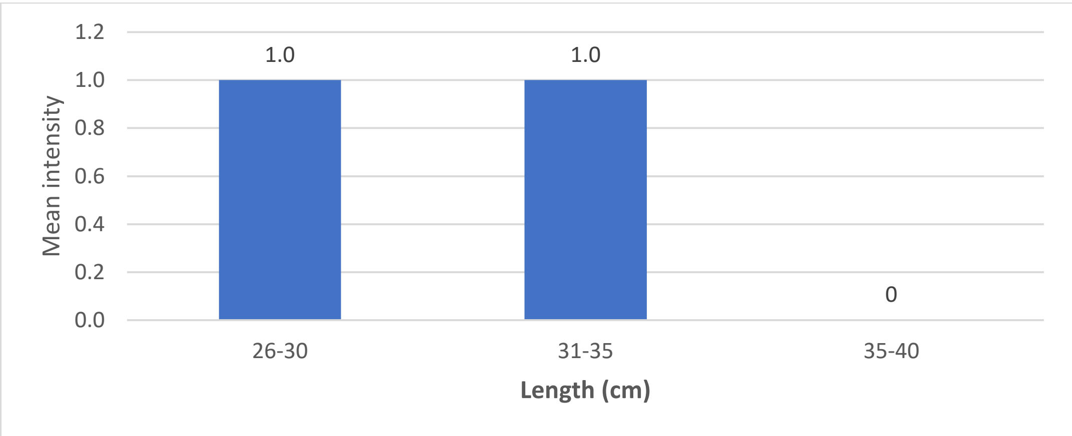

Figure 13. Mean intensities of fish parasites in relation to fish with length ≥25cm Calabar River

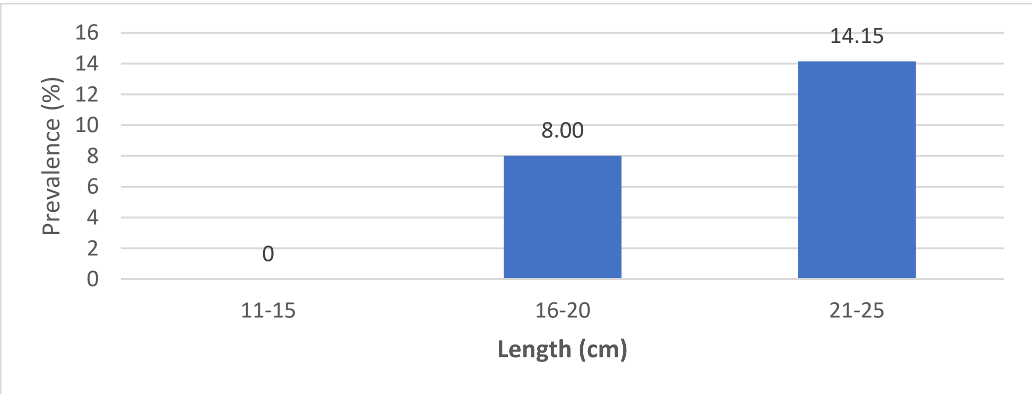

Figure 14. Prevalence of fish parasitic infections in relation to fish with length ≤ 25cm Great Kwa River

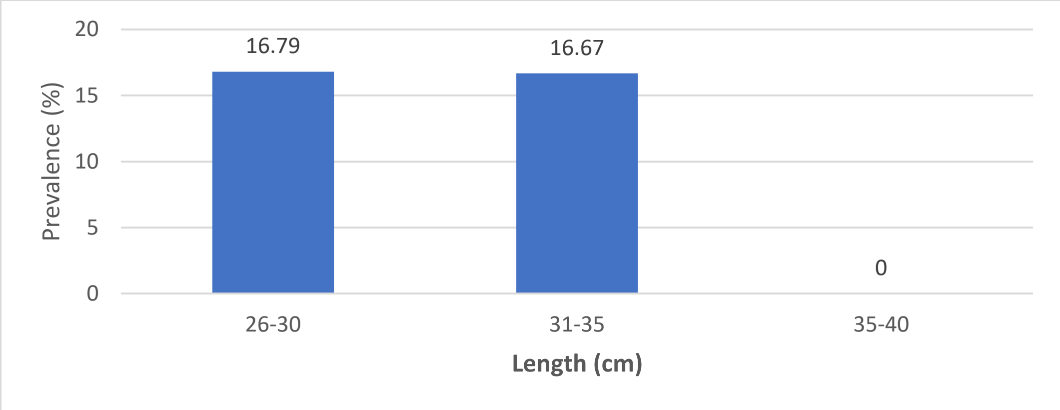

Figure 15. Prevalence of fish parasitic infections in relation to fish with length ≥ 25cm Great Kwa River

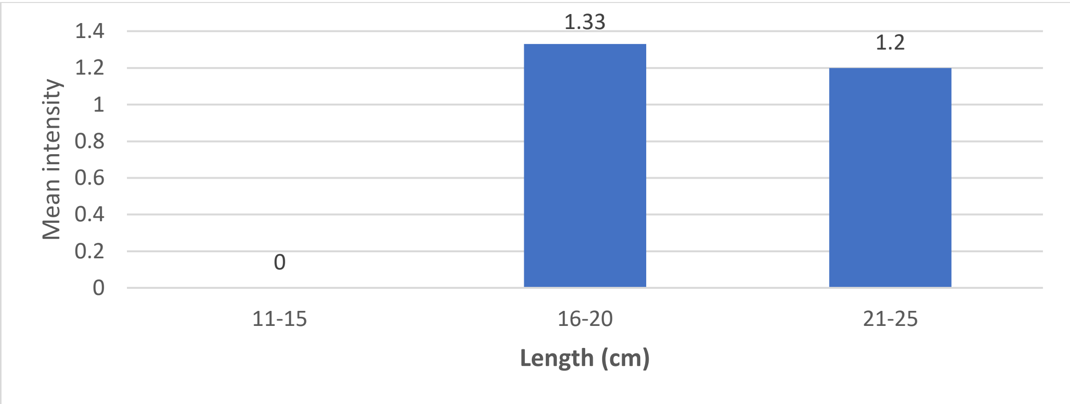

Figure 16. Mean intensities of fish parasites in relation to fish with length ≤ 25cm Great Kwa River

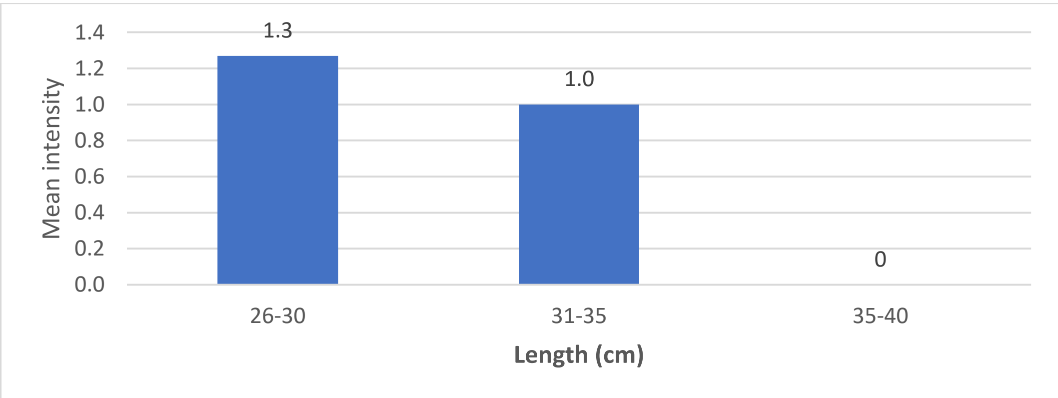

Figure 17. Mean intensities of fish parasites in relation to fish with length ≥25cm Great Kwa River

Table 6 Prevalence and Mean intensities of fish parasitic infections in relation to fish Length of various fish species Calabar River

Fish Species	Fish Length (Cm)	Average Length (Cm)	N. E.	N.I.	P (%)	N. P. R,	M.I. I
	11-15	-					
	16-20	16	**13**	**2**	**15.38**	**2**	**1.00**
Coptodon zillii	21-25	24	**18**	**3**	**16.67**	**3**	**1.00**
(Red-belly	26-30	27	**19**	**3**	**15.79**	**3**	**1.00**
tilapia)	31-35	-	**-**	**-**	**-**	**-**	**-**
	11-15	-	**-**	**-**	**-**	**-**	**-**
Coptodon	16-20	18	**16**	**1**	**6.25**	**1**	**1.00**
guineensis	21-25	23	**17**	**3**	**17.65**	**3**	**1.00**
(Guinean tilapia)	26-30	29	**17**	**2**	**11.75**	**2**	**1.00**
	31-35	-	**-**	**-**	**-**	**-**	**-**
	11-15	-	**-**	**-**	**-**	**-**	**-**
	16-20	19	**9**	**1**	**11.11**	**2**	**2.00**
Chrysichthys	21-25	24	**11**	**2**	**18.18**	**2**	**1.00**
auratus	26-30	27	**11**	**1**	**9.09**	**1**	**1.00**
	31-35	34	**10**	**2**	**20.00**	**2**	**1.00**
	36-40	38	**9**	**2**	**22.22**	**2**	**1.00**
	41-45	-	**-**	**-**	**-**	**-**	**-**
	46-50	-	**-**	**-**	**-**	**-**	**-**
	11-15	-	**-**	**-**	**-**	**-**	**-**
	16-20	17	**10**	2	20.00	2	**1.00**
Clarias	21-25	22	**11**	3	27.27	3	**1.00**
gariepinus	26-30	28	**11**	2	18.18	2	**1.00**
	31-35	33	**9**	1	11.11	1	**1.00**
	36-40	37	**9**	1	11.11	1	**1.00**

	41-45	-	-	-	-	-	-
	46-50	-	-	-	-	-	-
	11-15	-	-	-	-	-	-
Mugil cephalus	16-20	19	**17**	**1**	**5.88**	**2**	**2.00**
(Striped mullet)	21-25	23	**20**	**3**	**15.00**	**4**	**1.33**
	26-30	29	**12**	**1**	**8.33**	**1**	**1.00**
Total			**250**	**36**	**14.40**	**39**	**1.08**

Table 7. Prevalence and Mean intensities of fish parasitic infections in relation to fish Length of various fish species Great Kwa River

Fish Species	Fish Length (Cm)	Average Length (Cm)	N. E.	N.I.	P (%)	N. P. R.	M.I. I.
	11-15	-	-	-	-	-	-
	16-20	17	**16**	**1**	**6.25**	**2**	**2.00**
Coptodon zillii	21-25	23	**18**	**3**	**16.67**	**3**	**1.00**
(Red-belly	26-30	28	**16**	**3**	**18.75**	**4**	**1.33**
tilapia)	31-35	-	-	-	-	-	-
	11-15	-	-	-	-	-	-
Coptodon	16-20	19	**17**	**1**	**5.88**	**1**	**1.00**
guineensis	21-25	22	**20**	**2**	**10.00**	**3**	**1.50**
(Guinean tilapia)	26-30	27	**13**	**2**	**15.38**	**2**	**1.00**
	31-35	-	-	-	-	-	-
	11-15	-	-	-	-	-	-
	16-20	17	**13**	-	-	-	-
	21-25	22	**10**	**2**	**20.00**	**3**	**1.50**
Chrysichthys	26-30	28	**11**	**2**	**18.18**	**2**	**1.00**
auratus	31-35	33	**12**	**2**	**16.67**	**2**	**1.00**

	36-40	37	**4**	**-**	**-**	**-**	**-**
	41-45	-	**-**	**-**	**-**	**-**	**-**
	46-50	-	**-**	**-**	**-**	**-**	**-**
	11-15	-	**-**	**-**	**-**	**-**	**-**
	16-20	16	**12**	1	8.33	1	**1.00**
Clarias	21-25	23	**13**	2	15.38	2	**1.00**
gariepinus	26-30	26	**12**	3	25.00	3	**1.00**
	31-35	31	**12**	2	16.67	2	**1.00**
	36-40	32	**1**	**-**	**-**	**-**	**-**
	41-45	-	**-**	**-**	**-**	**-**	**-**
	46-50	-	**-**	**-**	**-**	**-**	**-**
	11-15	-	**-**	**-**	**-**	**-**	**-**
Mugil cephalus	16-20	18	**16**	**2**	**12.50**	**2**	**1.00**
(Striped mullet)	21-25	22	**19**	**2**	**10.52**	**2**	**1.00**
	26-30	28	**15**	**1**	**6.67**	**2**	**2.00**
Total			**250**	**31**	**12.40**	**36**	**1.16**

3.5 Prevalence, mean intensities, and frequencies of the various Class of parasites found in Calabar River

Prevalence, mean intensities, and frequencies in relation to the taxonomic Class of the parasites found in the Calabar River is presented in Table 8. Five taxonomic classes of parasites were found in the Calabar River, namely, Monogenea, Cestoda, Trematoda, Nematoda, and Acanthocephala. Cestoda, and Nematoda, recorded the highest number of species (4), with the highest frequency of occurrence and the highest prevalence of infection (4.40 %) in Nematoda followed by Cestoda with Prevalence of 4.31%, while the least prevalence (1.60%) and least number of representative species (2) were found in Acanthocephala. The highest mean intensity recorded was 1.67 by Monogenea, while the least was 1.00 by Cestodes, Nematoda and Acanthocephala

Table 8. Prevalence, mean intensities, and frequencies in relation to the taxonomic Class of the parasites found in the Calabar River

Parasite Class	Number of Species	Frequency	Number infected	Prevalence (%)	Number of parasites counted	Mean intensity
Monogenea	3	6	6	2.40	7	1.67
Cestoda	4	6	8	3.20	8	1.00
Trematoda	2	4	7	2.80	9	1.29
Nematoda	4	9	11	4.40	11	1.00
Acanthocephala	2	4	4	1.60	4	1.00
Total	**15**	**29**	**36**	**14.40**	**39**	**1.08**

3.6 Prevalence, mean intensities, and frequencies of the various Class of parasites found in Calabar River

Prevalence, mean intensities, and frequencies in relation to the taxonomic Class of the parasites found in the Calabar River is presented in Table 9. Five taxonomic classes of parasites were found in Great Kwa River, namely, Monogenea, Cestoda, Trematoda, Nematoda, and Acanthocephala. Cestoda recorded the highest number of species (4), the highest frequency of occurrence was recorded by Nematoda (7) and the highest prevalence of infection (3.60 %) followed by Monogenea (2.80). While the least prevalence (1.60 %) and least number of representative species (2) were Acanthocephala. The highest mean intensity recorded was 1.67 by Trematoda, while the least was 1.00 by Nematoda.

Table 9. Prevalence, mean intensities, and frequencies in relation to the taxonomic Class of the parasites found in the Great Kwa River

Parasite Class	Number of species	Frequency	Number infected	Prevalence (%)	Number of parasites counted	Mean intensity
Monogenea	2	4	7	2.80	9	1.29
Cestoda	4	6	5	2.00	6	1.20

Trematoda	2	5	6	2.40	7	1.67
Nematoda	3	7	9	3.60	9	1.00
Acanthocephala	2	3	4	1.60	5	1.25
Total	**13**	**25**	**31**	**12.40**	**36**	**1.16**

3.7 Results of Heavy Metals Concentration in Fish tissues

The heavy metals concentration in non-infected fish differ greatly from the heavy metal concentration in infected fish from the same water environment.

3.7.1 Uninfected Fish Tissues from both river

For uninfected fish as shown in table 10 from Calabar River the uninfected *Coptodon zillii* (Red-belly tilapia) tissues (Gills, Liver and Muscle) analyzed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.005±0.001, 0.033±0.001, 0.005±0.001, 0.007±0.001 and 0.048±0.002 respectively.

Coptodon guineensis (Guinean tilapia) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.005±0.001, 0.036±0.001, 0.004±0.001. 0.005±0.001 and 0.046±0.002 respectively.

Chrysichthys auratus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.007±0.001,0.037±0.001, 0.004±0.001, 0.006±0.001 and 0.044±0.002 respectively.

Clarias gariepinus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.005±0.001, 0.034±0.001, 0.006±0.001, 0.006±0.001 and 0.048±0.002 respectively.

Mugil cephalus (Striped mullet) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.005±0.001, 0.005±0.001, 0.007±0.001, 0.005±0.001 and 0.047±0.002 respectively.

For uninfected fish as shown in table 11 From Great Kwa River the *Coptodon zillii* (Red-belly tilapia) Gills, Liver and Muscle analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Copper (Cu) was 0.005±0.001, 0.037±0.001, 0.005±0.001 and 0.046±0.002 respectively while Nickel (Ni) was not found in Gills, Liver and Muscle.

Coptodon guineensis (Guinean tilapia) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.030±0.001, 0.005±0.001, 0.004±0.001 and 0.045±0.002 respectively.

Chrysichthys auratus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.006±0.001, 0.028±0.001, 0.005±0.001, 0.004±0.001 and 0.038±0.002.

Clarias gariepinus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.037±0.001, 0.005±0.001, 0.006±0.001 and 0.040±0.002.

Mugil cephalus (Striped mullet) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.039±0.001, 0.004±0.001, 0.005±0.001 and 0.043±0.002.

Table 10 Showing Result of Concentration of Heavy Metals in the tissue of uninfected fish tissue analysed from Calabar River

S/N	Fish Species	N.E.	U. I.	Organs observed	HEAVY METALS (mg/kg d.w) Cd	Zn	Pb	Ni	Cu
1	*Coptodon zillii* (Red-belly tilapia)	50	8	**Gills**	0.002±0.001	0.009±0.001	0.002±0.001	0.002±0.001	0.016±0.002
				Liver	0.002±0.000	0.010±0.001	0.001±0.001	0.003±0.001	0.018±0.002
				Muscle	0.001±0.001	0.014±0.001	0.002±0.001	0.002±0.001	0.014±0.002
				Total	**0.005±0.001**	**0.033±0.001**	**0.005±0.001**	**0.007±0.001**	**0.048±0.002**
2	*Coptodon guineensis* (Guinean tilapia)	50	6	**Gills**	0.002±0.001	0.012±0.001	0.001±0.001	0.002±0.001	0.015±0.002
				Liver	0.002±0.001	0.013±0.002	0.002±0.001	0.002±0.001	0.017±0002
				Muscle	0.001±0.001	0.011±0.001	0.001±0.001	0.001±0.001	0.014±0.002
				Total	**0.005±0.001**	**0.036±0.001**	**0.004±0.001**	**0.005±0.001**	**0.046±0.002**
3	*Chrysichthys auratus*	50	8	**Gills**	0.002±0.001	0.013±0.001	0.001±0.001	0.003±0.001	0.014±0.002
				Liver	0.004±0.001	0.012±0.001	0.002±0.001	0.002±0.001	0.019±0.002
				Muscle	0.001±0.001	0.012±0.001	0.001±0.001	0.001±0.001	0.011±0.002
				Total	**0.007±0.001**	**0.037±0.001**	**0.004±0.001**	**0.006±0.001**	**0.044±0.002**
4	*Clarias gariepinus*	50	9	**Gills**	0.002±0.001	0.011±0.001	0.002±0.001	0.003±0.001	0.017±0.002
				Liver	0.001±0.001	0.013±0.001	0.002±0.001	0.002±0.001	0.018±0.002
				Muscle	0.002±0.001	0.010±0.001	0.002±0.001	0.001±0.001	0.013±0.002
				Total	**0.005±0.001**	**0.034±0.001**	**0.006±0.001**	**0.006±0.001**	**0.048±0.002**
5	*Mugil cephalus* (Striped mullet)	50	5	**Gills**	0.002±0.001	0.002±0.001	0.002±0.001	0.002±0.001	0.014±0.002
				Liver	0.001±0.001	0.002±0.001	0.002±0.001	0.001±0.001	0.017±0.002
				Muscle	0.002±0.001	0.001±0.001	0.003±0.001	0.002±0.001	0.016±0.002
				Total	**0.005±0.001**	**0.005±0.001**	**0.007±0.001**	**0.005±0.001**	**0.047±0.002**

Table 11 Showing Result of Concentration of Heavy Metals in the tissue of uninfected fish tissue analysed from Great Kwa River

S/N	Fish Species	N.E.	U. I.	Organs observed	HEAVY METALS (mg/kg d.w) Cd	Zn	Pb	Ni	Cu
				Gills	0.002±0.001	0.011±0.001	0.002±0.001	0.000±0.000	0.017±0.002
1	*Coptodon zillii* (Red-belly tilapia)	**50**	**7**	**Liver**	0.002±0.001	0.014±0.001	0.001±0.001	0.000±0.000	0.018±0.002
				Muscle	0.001±0.001	0.012±0.001	0.002±0.001	0.000±0.000	0.011±0.002
				Total	**0.005±0.001**	**0.037±0.001**	**0.005±0.001**	**0.000±0.000**	**0.046±0.002**
				Gills	0.001±0.001	0.012±0.001	0.002±0.001	0.001±0.001	0.017±0.002
2	*Coptodon guineensis* (Guinean tilapia)	**50**	**5**	**Liver**	0.002±0.001	0.009±0.001	0.002±0.001	0.002±0.001	0.016±0.002
				Muscle	0.001±0.001	0.009±0.001	0.001±0.001	0.001±0.001	0.012±0.002
				Total	**0.004±0.001**	**0.030±0.001**	**0.005±0.001**	**0.004±0.001**	**0.045±0.002**
				Gills	0.001±0.001	0.011±0.001	0.002±0.001	0.001±0.001	0.017±0.002
3	*Chrysichthys auratus*	**50**	**6**	**Liver**	0.003±0.001	0.008±0.001	0.002±0.001	0.002±0.001	0.012±0.002
				Muscle	0.002±0.001	0.009±0.001	0.001±0.001	0.001±0.001	0.009±0.002
				Total	**0.006±0.001**	**0.028±0.001**	**0.005±0.001**	**0.004±0.001**	**0.038±0.002**
				Gills	0.001±0.001	0.012±0.001	0.001±0.001	0.003±0.001	0.013±0.002
4	*Clarias gariepinus*	**50**	**8**	**Liver**	0.002±0.001	0.014±0.001	0.002±0.001	0.001±0.001	0.015±0.002
				Muscle	0.001±0.001	0.011±0.001	0.002±0.001	0.002±0.001	0.012±0.002
				Total	**0.004±0.001**	**0.037±0.001**	**0.005±0.001**	**0.006±0.001**	**0.040±0.002**
				Gills	0.001±0.001	0.013±0.001	0.001±0.001	0.002±0.001	0.015±0.002
5	*Mugil cephalus* (Striped mullet)	**50**	**5**	**Liver**	0.002±0.000	0.012±0.000	0.002±0.001	0.002±0.001	0.013±0.002
				Muscle	0.001±0.001	0.014±0.001	0.001±0.001	0.001±0.001	0.015±0.001
				Total	**0.004±0.001**	**0.039±0.001**	**0.004±0.001**	**0.005±0.001**	**0.043±0.002**

3.7.2. Infected Fish Tissues

As shown in Table 12 from Calabar River, *Coptodon zillii* Gills, Liver and Muscle analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 004±0.001, 0.014±0.001, 0.004±0.001, 0.006±0.001 and 0.039±0.002 respectively.

Coptodon guineensis analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.007±0.001, 0.003±0.001, 0.004±0.001 and 0.036±0.002 respectively.

Chrysichthys auratus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.008±0.001, 0.003±0.001, 0.003±0.001 and 0.033±0.002 respectively.

Clarias gariepinus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.004±0.001, 0.006±0.001, 0.005±0.001, 0.005±0.001 and 0.045±0.002 respectively.

Mugil cephalus (Striped mullet) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.003±0.001, 0.004±0.001, 0.005±0.001, 0.004±0.001 and 0.045±0.002 respectively.

In table 13 For Great Kwa River *Coptodon zillii* (Red-belly tilapia) Gills, Liver and Muscle analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb) and Copper (Cu) was 0.004±0.001, 0.006±0.001, 0.004±0.001, 0.041±0.002 respectively, but Nickel (Ni) was not found in Gills, Liver and Muscle.

Coptodon guineensis (Guinean tilapia) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.003±0.001, 0.014±0.001, 0.004±0.001, 0.003±0.001 and 0.04±0.002 respectively.

Chrysichthys auratus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.005±0.001, 0.004±0.001, 0.004±0.001, 0.003±0.001 and 0.033±0.002 respectively.

Clarias gariepinus analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.003±0.001, 0.030±0.001, 0.004±0.001, 0.005±0.001 and 0.033±0.002 respectively.

Mugil cephalus (Striped mullet) analysed for heavy metals shows that Cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) was 0.003±0.001, 0.029±0.001, 0.003±0.001, 0.004±0.001 and 0.038±0.002 respectively.

Table 12 Showing result of Mean Concentration of Heavy Metals in the tissue of infected fish tissue analysed from Calabar River

S/N	Fish Species	N.E.	N. I.	Organs observed	HEAVY METALS (mg/kg d.w) Cd	Zn	Pb	Ni	Cu
1	*Coptodon zillii* (Red-belly tilapia)	**50**	**8**	**Gills**	0.001±0.001	0.004±0.001	0.002±0.001	0.003±0.001	0.014±0.002
				Liver	0.002±0.000	0.006±0.001	0.001±0.001	0.001±0.001	0.016±0.002
				Muscle	0.001±0.001	0.004±0.001	0.001±0.001	0.002±0.001	0.009±0.002
				Total	**0.009±0.001**	**0.014±0.001**	**0.004±0.001**	**0.006±0.001**	**0.039±0.002**
2	*Coptodon guineensis* (Guinean tilapia)	**50**	**6**	**Gills**	0.002±0.001	0.004±0.001	0.001±0.001	0.002±0.001	0.011±0.002
				Liver	0.001±0.001	0.002±0.002	0.001±0.001	0.001±0.00	0.012±0002
				Muscle	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.00	0.013±0.002
				Total	**0.004±0.001**	**0.007±0.001**	**0.003±0.001**	**0.004±0.001**	**0.036±0.002**
3	*Chrysichthys auratus*	**50**	**8**	**Gills**	0.001±0.001	0.003±0.002	0.001±0.001	0.001±0.001	0.014±0.002
				Liver	0.002±0.001	0.002±0.002	0.001±0.001	0.001±0.001	0.009±0.002
				Muscle	0.001±0.001	0.003±0.001	0.001±0.001	0.001±0.001	0.010±0.002
				Total	**0.004±0.001**	**0.008±0.001**	**0.003±0.001**	**0.003±0.001**	**0.033±0.002**
4	*Clarias gariepinus*	**50**	**9**	**Gills**	0.002±0.001	0.003±0.001	0.003±0.001	0.002±0.001	0.017±0.002
				Liver	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001	0.016±0.002
				Muscle	0.001±0.001	0.002±0.001	0.001±0.001	0.002±0.001	0.012±0.002
				Total	**0.004±0.001**	**0.006±0.001**	**0.005±0.001**	**0.005±0.001**	**0.045±0.002**
5	*Mugil cephalus* (Striped mullet)	**50**	**5**	**Gills**	0.001±0.001	0.002±0.001	0.001±0.001	0.002±0.001	0.014±0.002
				Liver	0.001±0.001	0.001±0.001	0.002±0.001	0.001±0.001	0.016±0.002
				Muscle	0.001±0.001	0.001±0.001	0.003±0.001	0.001±0.001	0.015±0.002
				Total	**0.003±0.001**	**0.004±0.001**	**0.005±0.001**	**0.004±0.001**	**0.045±0.002**

Table 13 Showing result of Mean Concentration of Heavy Metals in the tissue of infected fish tissue analysed from Great Kwa River

S/N	Fish Species	N.E.	N. I.	Organs observed	HEAVY METALS (mg/kg d.w)				
					Cd	Zn	Pb	Ni	Cu
				Gills	0.001±0.001	0.001±0.001	0.001±0.001	0.000±0.000	0.015±0.002
		50	7	Liver	0.002±0.001	0.004±0.001	0.001±0.001	0.000±0.000	0.017±0.002
1	*Coptodon zillii* (Red-belly tilapia)			Muscle	0.001±0.001	0.001±0.001	0.002±0.001	0.000±0.000	0.009±0.002
				Total	**0.004±0.001**	**0.006±0.001**	**0.004±0.001**	**0.000±0.000**	**0.041±0.002**
				Gills	0.001±0.001	0.004±0.001	0.001±0.001	0.001±0.001	0.014±0.002
2	*Coptodon guineensis* (Guinean tilapia)	50	5	Liver	0.001±0.001	0.006±0.00	0.001±0.001	0.001±0.001	0.012±0.002
				Muscle	0.001±0.001	0.004±0.001	0.002±0.001	0.001±0.001	0.015±0.002
				Total	**0.003±0.001**	**0.014±0.001**	**0.004±0.001**	**0.003±0.001**	**0.041±0.002**
				Gills	0.002±0.001	0.001±0.001	0.001±0.001	0.001±0.001	0.014±0.002
3	*Chrysichthys auratus*	50	6	Liver	0.001±0.001	0.001±0.001	0.001±0.001	0.001±0.001	0.010±0.002
				Muscle	0.002±0.001	0.002±0.001	0.002±0.001	0.001±0.001	0.009±0.002
				Total	**0.005±0.001**	**0.004±0.001**	**0.004±0.001**	**0.003±0.001**	**0.033±0.002**
				Gills	0.001±0.001	0.011±0.001	0.001±0.001	0.002±0.001	0.012±0.002
4	*Clarias gariepinus*	50	8	Liver	0.001±0.001	0.009±0.001	0.002±0.001	0.001±0.001	0.012±0.002
				Muscle	0.001±0.001	0.010±0.001	0.001±0.001	0.002±0.001	0.009±0.002
				Total	**0.003±0.001**	**0.030±0.001**	**0.004±0.001**	**0.005±0.001**	**0.033±0.002**
				Gills	0.001±0.001	0.010±0.001	0.001±0.001	0.001±0.001	0.014±0.002
5	*Mugil cephalus* (Striped mullet)	50	5	Liver	0.001±0.000	0.008±0.000	0.001±0.001	0.002±0.001	0.010±0.002
				Muscle	0.001±0.001	0.011±0.001	0.001±0.001	0.001±0.001	0.014±0.001
				Total	**0.003±0.001**	**0.029±0.001**	**0.003±0.001**	**0.004±0.001**	**0.038±0.002**

3.8 Bioaccumulation Factor (BAF)

3.8.1. Bioaccumulation Factor (BAF) in fish species from the Calabar River

The Bioaccumulation Factors (BAFs) (mg/kg d.w) values of heavy metals calculated for tissues (gills, liver and muscle) of each fish are shown in Table 14. The heavy metals when arranged in an increasing order are as follows: *Coptodon zillii* Zn < Pb < Cd < Cu < Ni, *Coptodon guineensis* Zn < Pb < Cd & Ni < Cu, *Chrysichthys auratus* Zn < Pb < Ni < Cu < Cd; *Clarias gariepinus* Zn < Cd < Pb < Ni & Cu and *Mugil cephalus* Zn < Cd < Pb < Ni < Cu

3.8.2 Bioaccumulation Factor (BAF) in fish species from the Great Kwa River

The Bioaccumulation Factors (BAFs) (mg/kg d.w) values of heavy metals calculated for tissues (gills, liver and muscle) of each fish are shown in Table 15. The heavy metals when arranged in an increasing order are as follows: *Coptodon zillii* Ni < Zn < Pb & Cd < Cu; *Coptodon guineensis* Zn < Ni < Cd < Pb < Cu; *Chrysichthys auratus* Zn < Ni < Cu < Pb < Cd; *Clarias gariepinus* Cd < Ni < Cu < Zn < Pb and *Mugil cephalus* Cd & Pb < Ni < Zn < Cu

Table 14 Showing Result of Bioaccumulation Factor (BAF) in Calabar River

S/N	**Fish Species**	**Heavy Metals** (mg/kg d.w)				
		Cd	**Zn**	**Pb**	**Ni**	**Cu**
1	*Coptodon zillii* (Red-belly tilapia)	0.666667	0.35	0.571429	1	0.764706
2	*Coptodon guineensis* (Guinean tilapia)	0.666667	0.175	0.428571	0.666667	0.705882
3	*Chrysichthys auratus*	0.666667	0.2	0.428571	0.5	0.647059
4	*Clarias gariepinus*	0.666667	0.15	0.714286	0.833333	0.882353
5	*Mugil cephalus* (Striped mullet)	0.5	0.075	0.571429	0.666667	0.882353

Table 15 Showing Result of Bioaccumulation Factor (BAF) in Great kwa River

S/N	**Fish Species**	**Heavy Metals** (mg/kg d.w)				
		Cd	**Zn**	**Pb**	**Ni**	**Cu**
1	*Coptodon zillii* (Red-belly tilapia)	0.666667	0.142857	0.666667	0	0.788462
2	*Coptodon guineensis* (Guinean tilapia)	0.5	0.333333	0.666667	0.428571	0.788462
3	*Chrysichthys auratus*	0.833333	0.095238	0.666667	0.428571	0.634615
4	*Clarias gariepinus*	0.5	0.714286	0.833333	0.571429	0.634615
5	*Mugil cephalus* (Striped mullet)	0.5	0.690476	0.5	0.571429	0.730769

3.9 Health Risk Assessment using the Hazard Index (HI)

3.9.1. Hazard Index (HI) for fishes caught from Calabar River

The Hazard Index (HI) for all the heavy metal concentrations in the Gills, Liver and Muscles of the various fish species in the Calabar River are presented in Tables 16, 17, and 18 respectively. The Results show that the calculated HI value ≤ 1 showing that the non-carcinogenic risk effect is low for the exposed consumers.

3.9.2 Hazard Index (HI) for fish from the Great Kwa River

The Hazard Index (HI) for all the heavy metal concentrations in the Gills, Liver and Muscles of the various fish species in the Great Kwa River are presented in Tables 19, 20, and 21 respectively. The Tables show that the calculated HI value ≤ 1 showing that the non-carcinogenic risk effect is low for the exposed consumers.

Table 16 Showing Result of THQ & HI of Gills in Calabar River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.003338	0.000044	0.001669	0.000501	0.001168	0.00672
2	*Coptodon guineensis* (Guinean tilapia)	0.006676	0.000044	0.000834	0.000334	0.000918	0.008806
3	*Chrysichthys auratus*	0.003338	0.000033	0.000834	0.000167	0.001168	0.005541
4	*Clarias gariepinus*	0.006676	0.000033	0.002503	0.000334	0.001419	0.010965
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000022	0.000834	0.000334	0.001168	0.005697

Table 17 Showing Result of THQ & HI of Liver in Calabar River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.006676	0.000066	0.000834	0.000167	0.001335	0.009079
2	*Coptodon guineensis* (Guinean tilapia)	0.003338	0.000022	0.000834	0.000167	0.001001	0.005363
3	*Chrysichthys auratus*	0.006676	0.000022	0.000834	0.000167	0.000751	0.00845
4	*Clarias gariepinus*	0.003338	0.000011	0.000834	0.000167	0.001335	0.005685
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000011	0.001669	0.000167	0.001001	0.006186

Table 18 Showing Result of THQ & HI of Muscle in Calabar River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.003338	0.000044	0.000834	0.000334	0.000751	0.005302
2	*Coptodon guineensis* (Guinean tilapia)	0.003338	0.000011	0.000834	0.000167	0.001085	0.005435
3	*Chrysichthys auratus*	0.003338	0.000033	0.000834	0.000167	0.000834	0.005207
4	*Clarias gariepinus*	0.003338	0.000022	0.000834	0.000334	0.001001	0.00553
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000011	0.002503	0.000167	0.001252	0.007271

Table 19 Showing Result of THQ & HI of Gills in Great kwa River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.003338	0.000011	0.000834	0	0.001252	0.005435
2	*Coptodon guineensis* (Guinean tilapia)	0.003338	0.000044	0.000834	0.000167	0.001168	0.005552
3	*Chrysichthys auratus*	0.006676	0.000011	0.000834	0.000167	0.001168	0.008856
4	*Clarias gariepinus*	0.003338	0.000122	0.000834	0.000334	0.001001	0.00563
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000111	0.000834	0.000167	0.001168	0.005619

Table 20 Showing Result of THQ & HI of Liver in Great kwa River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.006676	0.000045	0.000834	0	0.001419	0.008973
2	*Coptodon guineensis* (Guinean tilapia)	0.003338	0.000066	0.000834	0.000167	0.001001	0.005407
3	*Chrysichthys auratus*	0.003338	0.000011	0.000834	0.000167	0.000834	0.005185
4	*Clarias gariepinus*	0.003338	0.0001	0.001669	0.000167	0.001001	0.006275
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000089	0.000834	0.000334	0.000834	0.005429

Table 21 Showing Result of THQ & HI of Muscle in Great kwa River

S/N	Fish Species	Target Hazard Quotient (THQ)					HI
		Cd	Zn	Pb	Ni	Cu	
1	*Coptodon zillii* (Red-belly tilapia)	0.003338	0.000011	0.001669	0	0.000751	0.005769
2	*Coptodon guineensis* (Guinean tilapia)	0.003338	0.000044	0.001669	0.000167	0.001252	0.00647
3	*Chrysichthys auratus*	0.006676	0.000022	0.001669	0.000167	0.000751	0.009285
4	*Clarias gariepinus*	0.003338	0.000111	0.000834	0.000334	0.000751	0.005368
5	*Mugil cephalus* (Striped mullet)	0.003338	0.000122	0.000834	0.000167	0.001168	0.00563

Discussion

In the two water bodies covered in this study, most of the fish species were found with parasites. This is in tandem with the work of Iyaji and Eyo (2008), who stated that the number of fish species infected in a host population could be very significant. Oniye *et al*. (2004) and Kadlec *et al*. (2003) elaborated further that if carefully observed with higher techniques, all fish species may be infected with ecto-parasites or endo-parasites. The fish species infected with helminth and percentage prevalence of infection shows that *Coptodon zillii*, *Coptodon guineensis*, *Chrysichthys auratus*, *Clarias gariepinus* and *Mugil cephalus* (15.00%, 11.00%, 1400%, 17.00% and 10.00%) respectively as shown in Table 1.

This study shows that there was no significant different across the two sites at the $P \leq 0.05$ ($\propto = 0.05$). This finding agrees with the work of Antoine *et al*., (2017) who stated that this could be because of favourable environments for parasites species. The findings shows that there is linear relationship between average weight or length and prevalence of infection. With sufficient statistical evidence at $\propto = 0.05$ significant level**.** The mean intensities of fish infections in relation to weight of fish for relatively small weight seems to be the same in Calabar River but different in Great kwa River. while for large weight fishes as presented seems to be higher in fish weight 400-499 from both Rivers as shown in Figures 6, 7, 8 and 9 respectively. This finding is in line with the work of Eshraga *et al*., (2021) who stated that Prevalence of parasites based on weight showed that weight of the *Clarias lazera* range 38-1020g and 600-2200g gave high prevalence, recommending that bigger fish may ingest a bigger amount of food and which may be attributed to the fact that larger size *C. lazera* provides a larger surface zone for parasitic infection than the smaller ones. Also the result of Iboh *et al*., (2016), agreed with this study, especially in *Chrysichthys auratus***,** *Chrysichthys nigrodigitatus* and *Clarias gariepinus* from Great Kwa River, Ajala and Fawole (2014), Aliyu and Solomon (2012), who observed that infection rate increases with increasing fish weight in *Clarias gariepinus* and Oniye *et al*., (2004) who reported that the increase in fish size is a reflection of increase in length and weight, which is considered as a measure of age.

The prevalence of fish infections in relation to length of fish for relatively small and large fish in Calabar and Great Kwa River increases with increase in length. The Mean intensity for relatively small fish length decrease with increase fish length while large fish length seems to be constant in Calabar River, but decreases with increase length in Great Kwa River as show in figure 10,11, 12, 13, 14, 15, 16 and 17 respectively. This is in agreement with the work of Brickle *et al*. (2005) who reported that larval Acanthocephalan (*Corynosoma bullosum)* showed a significant increase in abundance with increasing host length, suggesting that parasite accumulates more with host length/age and is confirmed by Iyaji *et al*., (2009). The present work showed that 4 species of Monogenean, 3 species of Cestodes, 4 species of Trematodes (Digenean), 5 species of Nematodes and 2 species of acanthocephalans were recovered. When compared with the findings of Adou *et al*., (2021) who recovered four monogenean, two trematodes, one nematode and one acanthocephalan from fish and the work of Iboh, (2016) who recovered one monogenean, one cestode, no trematodes and four Nematodes without any acanthocephalan from Great Kwa River and Ekanem *et al*., (2014) who also recovered one species of trematodes, one species of Cestodes, one species of nematodes, one species of Acanthocephalan from Calabar River. The parasite fauna may have said to be poor and could be explained largely in terms of the frequency of contact between the fish and the infective stage of the parasite (Nwani *et al*. 2008).

Comparing result of the concentration of heavy metals between non-infected fish tissues and infected fish tissues from Calabar River and Great Kwa River at p-value of 0.001 and 0.001 respectively, for infection status (that is, non-infected and infected fish tissues) This is less than the 0.05 significant level of the test and indicates that the concentration of heavy metals (Cadmium, Zinc, Lead, Nickel, and Copper) in non-infected fish tissues was significantly different from that of infected fish tissues. This result agrees with the work of Rehman *et al*., (2018) who stated that Heavy metal content was significantly higher in non-infected than infected farmed and wild *Oreochromis niloticus* tissues. This may be due to “Parasites” accumulating high levels of metal from the fish into their tissues, thereby acting as metal sinks for their fish host and helping in their survival in the presence of toxins. This was supported by Eissa *et al*. (2012) and Asuquo *et al*, (2004) in their work from Cross River. Similarly, AlHasawi, 2019 and Mehana *et al*., 2020 stated that gastrointestinal parasitic worms appeared capable to decrease levels of heavy metals in fish muscle by accumulating them.

By assessing the health risk caused by the accumulation of heavy metals in the fish tissue analysed, shows that in Calabar River and Great Kwa River the bioaccumulation factor (BAF) was less than one (1) (BAF < 1), except for Nickel (Ni) in *Coptodon zillii* (Red-belly tilapia) from Calabar River whose BAF is equal to one (1), This result is in consonant with findings of Chee *et al*., (2015) who stated that the ranges for Fe and Ni were lower compared to Pb and Cu in the tissue of fish. The heavy metal concentration analysed for BAF did not exceed the food safety guidelines stated by US Food and Drug Administration (USFDA, 2007), food regulation of European Union (EC, 2006), and National Food and Drug Administration (NFDAC, 2019). Therefore, it is suggested that the consumption of the fish collected from the river should not pose toxicological risks to the consumers, but it should be consumed with caution.

The value of THQ and Hi for the heavy metals (Cd, Zn, Pb, Ni and Cu) in the tissues (Gills, Liver and Muscles) of all the fish species and across the two sites shows that the value is less than 1 (Hi < 1). This is an indication that there is no health risk in the consumption of fish from the study sites. Agreeing with this study is Storelli, (2008) who measured Silver (Hg), Cd, and Pb concentrations in fish tissues from the Adriatic water and reported the THQs of Cd (0.01–0.04) and Pb (0.002–0.18) from consumption of fish being less than 1, suggesting that health risk was insignificant. Also, the work of Chee *et al*., (2015) is in support of this study, who stated that since the THQ values for Cd, Cu, Fe, Ni, and Zn in the widely consumer part (muscles) from their study is below 1, which indicated that there was no health risk in fish consumption in the areas.

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