Original Research Article

Internal Parasitic Helminth Infecting Reared Fishes from the West Region of Cameroon: Epidemiological Profile and Effects on Fish Health

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Abstract: Intensification of the fish farming sector in Cameroon can result to reduction of profitability and public health concerns due to emergence of parasites amongst which zoonotic ones. Unfortunately, limited and outdated data are available on internal parasites of reared fish as well as their impact on the infected fish. A total of 2254 live fish samples of males and females were randomly obtained made up of Clarias gariepinus (692), Cyprinus carpio (593) and Oreochromis niloticus (969). The skin, the gastrointestinal tract of the fish was examined for the presence of parasite, using standard procedures. An overall prevalence of 8.47% coupled with a very low intensity was assessed. This study revealed a diverse parasitic fauna made up of Acanthocephala sp. (4.84%), Cappilaria sp. (1.91%), Eustrongylides sp. (1.06%), Camallanus sp. (1.2%) and Orientatractis sp. (0.34%). Meanwhile, intensities mean values were higher in Cappilaria sp. followed by Eustrongyloides sp., Camallanus sp. and finally Acanthocephalus sp. Prevalence of internal parasites was higher in Cyprinus carpio (8.77%). Clarias Gariepinus on the other hand, had a higher intensity. Fish were mostly infected during the dry season. Nevertheless, a high parasitic load was observed in the rainy season. Specimens collected in the earthen ponds show a higher prevalence ($p < 0.05$), while those in concrete ponds had a higher infection intensity. Females were more prevalent contrary to males which have a higher intensity. Parasites were identified from the body cavities and gastrointestinal tracts of fishes. Comparison of Length/Weight relationship and Fulton condition index K does not show any differences between the parasitized and non-parasitized specimens. Parasites with a zoonotic potential were detected in this study, highlighting the importance of intensifying biosecurity and parasite control measures in fish farms in West Cameroon.

Keywords: Endoparasites, Fish farms, Food security, West Cameroon.

1. Introduction

Fish serves as a good source of animal protein for man and livestock and accounts for over 40% of the protein diet of two–third of the global population (FAO, 2016). In addition, fish farming contributes to poverty alleviation in many communities of developing countries (Adeosun et al., 2019; Ntsama et al. , 2018; Efole et al., 2016; FAO, 2016).

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Certain farming practices can compromise the water quality, resulting in parasites proliferation. Parasites constitute a major limiting factor to the growth performance of fish (Bichi and Yelwa, 2010). These conditions favor stress, which in turn weaken the immune system of fish (Boungou et al., 2013) and increase their susceptibility to secondary infections such as viruses, fungi and bacteria. Various authors have revealed the different effects of parasites on fish: alteration of biology and behavior (Lafferty, 2008); lowering of immune capability, induction of blindness (Echi et al., 2009 a, b); morbidity, mortality, growth and fecundity reduction (Nmor et al., 2004) and mechanical injuries depending on the parasite species and burden (Echi et al., 2009 a, b); nutrient devaluation (Hassan et al., 2010) and gross economic losses for fish farmers, as their products are rejected by consumers (Fonkwa et al. 2022). Besides, infected fish may constitute zoonotic threats to animal and human consumers (Elsheikha and Elshazly, 2008).

To the best of our knowledge, in Cameroon, various studies related to the internal helminths of fish from different water bodies have been carried out (Tchoumboue, 1992; Domwa, 2012; Nack et al. 2022; Fonkwa et al., 2023), but none in culture systems. No data is available on the risks factors of the internal helminths infections in farmed fishes nor their effects on the fish's health. This study aims at evaluating the prevalence and mean intensity of helminth infections in fish, the associated risk factors and their effect on their health status. The choice of fish here is based on their socioeconomical importance, their edibility as farmed fishes (Clarias gariepinus, Cyprinus carpio and Orechromis niloticus) captured in the West Region of Cameroon.

2. Material and Methods

2.1 Study Area

The research was conducted in three Administrative Divisions: Menoua, Noun and Hauts-plateaux, located in the West Region of Cameroon (9°50′–10°20′ E and 5°10′–5°40′ N). The West Region has a typical Sudano-Guinean climate characterized by a short dry season (mid-November–mid-March) and a long rainy season (mid-March–Mid-November) with a temperature range of 20–27 ºC, and 16–23 ºC respectively. The average annual rainfall is about 1600 mm, and the relative humidity varies from 49 to 97.9% (IRAD, 2013).

2.2 Fish Sampling

A list of fish farmers was obtained from the Fisheries Department in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West region of Cameroon. Those with active fish ponds were identified and their verbal consent was obtained before sampling. Since the previously reported data was lacking, a default prevalence rate of 50% was used to estimate the number of fish required for detecting ≥1 infested fish with a desired 95% confidence and precision of ≥5% (Thrusfield, 2007). Hence, a total of 2254 randomly selected fresh specimens comprising Clarias gariepinus (692), Cyprinus carpio (593) and Oreochromis niloticus (969) were collected alive from December 2018 to December 2019 (Ngueguim et al., 2020) from the nine fish farms (3 per administrative division) located in different sub-divisions. Fish samples were thereafter transported during the early hours (9:00–10:00) of the day in a sanitized plastic container with water from ponds Source to the Ichthyology and Applied Hydrobiology Laboratory of the University of Dschang for growth assessments and parasitological examination.

2.3 Morphometric Measurements and Sex Grouping

Standard and total lengths (in cm) were measured using a graduated meter rule, while fish weight (in g) was determined using electronic scale (Mettler Toledo electronic weighing balance–PB8001; 0.1g error margin).

Fish sizes (x) and weights (X) were classified according to Shehata et *al.* (2018) and Biu et *al.* (2014) respctively as summarized in Table 1.

According to the methods described by Akombo et *al* ., 2013 and Mbakane et *al.* , 2010, fish samples were separated into male and female respectively after dissection and inspection of the gonads. The frequency distribution of the fish sex as per the species is summarized on Table 1.

Table 1 Community structure of cultured fishes collected in Menoua, Noun and Hauts-plateaux administrative divisions of the West region of Cameroon.

Fish species	Sex	Weight classes (X) (g)					Size classes (x) (cm)		
		$X < 50$	$50 < X \leq 100$	$100 < X \leq 150$	$150 < X \leq 200$	$X > 250$	Small	Large	Total
Oreochromis niloticus	♂	219	72	81	0	0	281	91	372
	♀	349	69	118	61	0	407	190	597
	♂+♀	568	141	199	61	0	688	281	969
Cypinus carpio	♂	77	113	49	4	79	248	74	322
	♀	92	75	24	27	53	167	104	271
	♂+♀	169	188	73	31	132	415	178	593
Clarias gariepinus	♂	54	105	84	52	9	303	1	304
	♀	64	173	24	118	9	388	0	388
	♂+♀	118	278	108	170	18	691	1	692
Total	♂	350	290	214	56	88	832	166	998
	♀	505	317	166	206	62	962	294	1256
	♂+♀	855	607	380	262	150	1,794	460	2254
	(%)	(37.93%)	(26.93%)	(16.86%)	(11.62%)	(6.65%)	79.59%	20.41%	(100%)

♂: male; ♀: female.

3. Growth Characteristics Assessment

3.1 The Weights, Standard Lengths and Total Lengths of the Fishes Were Recorded

Condition factor (K) of the fish was determined to evaluate the health status or their well-being using the formula $K = 100W/ L^3$ (Dekić et *al.*, 2016; Akombo et *al.*, 2013) where: K and W stand respectively for Condition factor and W the weight of fish in grams (g) and L for the standard length (cm). The regression analysis was carried out to assess the relationship between the increase in length with a weight gain of the fish as reported by Akombo et *al*. (2013), i.e. $W = aL^b$, where W = Fish weight in grams (g); L = Total Length (TL) of fish in centimeters (cm); a = Scaling Constant; b = Allometric growth coefficient. The "a" and "b" values were obtained from a linear regression of the fish length and weight by transforming the equation into linear regression model as follows: Log W = Log a + b Log L.

4. Parasitological Study

Standard parasitological procedures were used for fish examination and identification the internal helminths (Ali, 2009, Noga, 2010, Farman *et al*., 2015). The body cavity and visceral surfaces, were examined for parasites. Investigation of the gastro-intestinal tract specifically the stomach and intestine were carried out. Each fish was dissected on the ventral side from the anal opening to the anterior in order to expose the digestive tracts with the aid of a dissecting set. The digestive tracts were thereafter removed, cut into parts (Stomach and intestine) and placed inside well emptied Petri-dishes containing 0.09% normal saline that is NaCl solvent (1-gram NaCl and 10 ml of distilled water). The normal saline caused the wriggling movement of worms which were quickly recovered and counted. The recognition of the worms was enhanced by the wriggling movements on emergence. Every single segment was cut longitudinally and observed under dissecting light microscope in 10X and 30X magnification (Paperna, 1991). The appearance of worm was assessed through its wriggling physical motion in the saline solution. Parasitic fauna observed were counted and preserved in 5% formalin.

The parasites observed from the respective organs were identified up to species level morphologically using the standard identification guides (Paperna, 1980) and with standard keys in texts (Paperna, 1996; Chandra, 2004; Pouder et *al*., 2005), counted and recorded. The sample worms were examined with naked eyes and using hand

lens when necessary.

An infected fish sample was coded as 1 and uninfected as 0. The prevalence (*Pr*) or infection rate and mean intensities (*I*) of infections were calculated according to Bush *et al.* (1997).

The classification of the prevalence provided by Valtonen et *al.* (1997) then modified by Fonkwa et *al.* (2022) was used to categorize the prevalence as very low ($Pr < 10\%$), low ($10 \leq Pr \leq 50\%$) or high ($Pr > 50\%$) corresponding respectively to rare, secondary and core parasites.

The mean intensities (parasite load) were categorized as very low ($I < 10$), low ($10 \leq I \leq 50$), average ($50 < I \leq 100$) or high ($I > 100$), as previously described by Bilong and Njiné (1998).

4.1 Data Analysis

Data was entered into the computer, cleaned and sorted using Microsoft Excel 2016 and analyzed using the Statistical Package for Social Sciences (SPSS version 25.0). Descriptive statistics consisting of frequencies were computed for different data categories to facilitate comparisons of parasitic infestations between fish farms, fish species and other risk factors. Chi square test was used to compare proportions and prevalence of parasite infections (Kouam et *al.,* 2018). Linear regression table was used to determine statistical significance of the results derived from the length and weight analysis of infected and uninfected fish species. The relationships between factors such as host, sex, weight, total length, locality, and parasitic infection were obtained from pooled data using analysis of variance (ANOVA). The significance level was set at $p < 0.05$.

4.2 Ethical Approval

The study is not reporting results from an experiment on animals or humans. The researchers performed risk assessment to avoid hazards to persons involved in the project. Permission for the study and Ethical approval were obtained from the required authorities in the West of Cameroon [Regional delegation of Livestock, Fisheries and Animal Industries (RDEPIA) and Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon] before carrying out the study. The purpose of the study was explained (with the assistance of local veterinary and fisheries practitioners, community leaders and trusted intermediaries) to fish farmers in the selected administrative divisions.

5. Results

5.1 Overall Prevalence and Mean Intensity of Internal Helminth Infections in Cultured Fish

The overall prevalence and mean intensity of internal helminth infections of each fish species examined are presented in Figure 1. Out of the 2,254 fish samples, 191 were infested regardless the parasitic taxon given the overall very low prevalence of (8.47%; CI at 95% [7.39–9.70]). Acanthocephalan (109; 4.84% [4.02–5.80]) and Nematods (92; 4.08% [3.34–4.98]) were the sole gastrointestinal helminth recorded with insignificant ($p > 0.05$) difference of their prevalence. Acanthocephalus sp. (109; 4.84% [4.02–5.80]) was the only species belonging to acanthocephalan group while, Nematods were made up of 4 species namely Camallanus sp. (27; 1.20% [0.82–1.74)]), Eustrongylides sp. (24; 1.06% [0.72–1.58]), Capillaria sp. (43; 1.91% [1.42–2.56]) and Orientatractis sp. (8; 0.35% [0.18–0.70]). Though Acanthocephalus sp. had the highest prevalence ($p < 0.05$) compared to other parasitic species, no core parasite was recorded. As far as the mean intensities are concerned, the overall value was very low. Capillaria sp. and Camallanus sp had respectively the highest and lowest parasite load ($p < 0.05$) compared to others.

5.2 Prevalence and Intensity of Endoparasites According to Host Fish

Out of the samples examined for parasitological study, 14.93%, 10.15%, 6.76% and of Oreochromis niloticus, Cyprinus carpio, and Clarias gariepinus, respectively were infested with different parasite species. O. niloticus was the most infected ($p < 0.05$).

The infection intensity of the studied fish species is summarized in Figure 2.

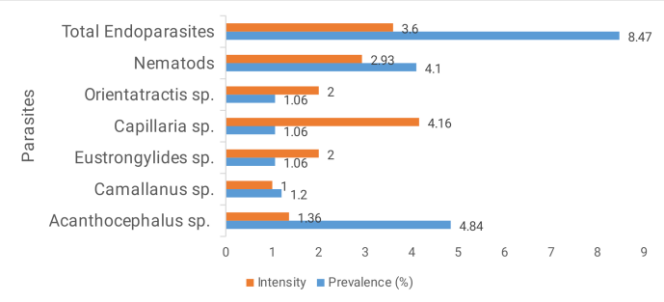

Figure 1 Overall prevalence and mean intensity of endoparasites infecting cultured fish in the West Region of Cameroon.

The parasite load in O. niloticus was significantly higher ($p < 0.05$) compared to the other species (Figure 2). However, it was less but than 5 worms per host. Contrary to C. carpio where the intensity of Capillaria sp. was significantly lower ($p < 0.05$) than the ones for O. niloticus and C. gariepinus which did not vary significantly.

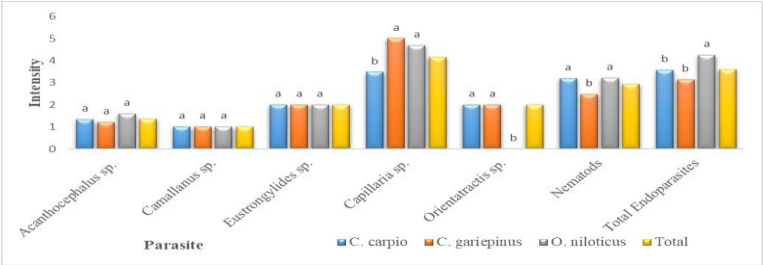

Figure 2 Intensity of types of endoparasites depending on fish specie.

a, b: The bars assigned different letters differ significantly ($p < 0.05$), for a given parasite.

5.3 Prevalence of Infection and Mean Intensity Related to Host Species and Season

Table 2 summarized the prevalence of parasitic infection in relation to host species and season. The prevalence was significantly higher ($p < 0.05$) during the dry season than the rainy season (**Table 2**). *Orientatractis* sp particularly was observed only in the rainy season in *Cyprinus carpio* and *Clarias gariepinus*, but absent *Oreochromis niloticus* during both seasons.

Table 2 Prevalence of gastrointestinal infection related to host species and season in the West Region of Cameroon.

Parasites	**Cyprinus carpio**		**Total (N_3 = 593)**	**Clarias gariepinus**		**Total (N_5 = 692)**	**Oreochromis niloticus**		**Total (N_8 = 969)**	**Total**	
	Rainy (N_1 = 255)	Dry (N_2 = 338)		Rainy (N_4 = 339)	Dry (N_4 = 353)		Rainy (N_6 = 382)	Dry (N_7 = 587)		Rainy (N_9 = 976)	Dry (N_{10} = 1278)
Acanthocephala											
Acanthocephalus sp.	7.84a	9.47a	8.77a	0.88b	7.65a	4.34b	2.36a	3.07a	2.79b	3.28b	6.03a
Nematods	7.45a	3.55b	5.23a	6.19a	3.68a	4.91a	5.24a	1.19b	2.79b	6.15a	2.50b
Camallanus sp.	0.78a	2.37a	1.69a	0.59b	3.12a	1.88a	1.05a	0.00b	0.41b	0.82b	1.49a
Eustrongylides sp.	0.78a	1.18a	1.01a	1.47a	0.57a	1.01a	1.05a	1.19a	1.14A	1.13a	1.02a
capillaria sp.	5.49a	2.07b	3.54a	2.65a	0.00b	1.30b	3.40a	0.00b	1.34b	3.69a	0.55b
Orientatractis sp.	0.78a	0.00a	0.34a	1.77a	0.00b	0.87a	0.00a	0.00a	0.00a	0.82a	0.00a
Total Endoparasites	14.51A	11.24A	12.65α	7.08B	11.61A	9.39β	7.33B	3.92B	5.26¥	9.12a	7.98b

$N_{1–10}$: number of fish for each factor considered; a, b, c : Same letters in column for the same category are not significantly different ($p > 0.05$); A, B: Same letters for a category in a line are not significantly different ($p > 0.05$); α, β, ¥: Same letters for a total of a fish species are not significantly different ($p > 0.05$).

The mean intensity related to season is illustrated in Figure 3. Globally, the parasitic load was significantly higher ($p < 0.05$) in the rainy season than in the dry season (Figure 4), as well as the intensities of nematods and Acanthocephala. However, *Camallanus* sp. and *Eustrongylides* sp parasitic load remained unchanged between seasons.

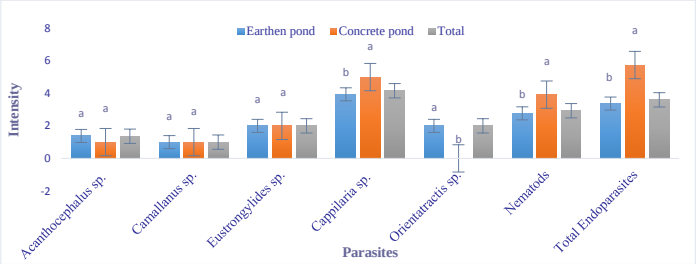

Figure 3 Intensity of types of endoparasites depending on the culture facilities.

a, b: The bars assigned different letters differ significantly ($p < 0.05$), for a given parasite.

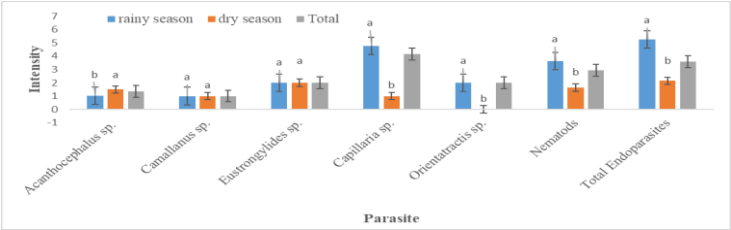

Figure 1 Intensity of infestations according to the endoparasites genera and the season.

a, b: The bars assigned different letters differ significantly ($p < 0.05$), for a given parasite.

5.4 Parasite infection rate and parasite load depending on the host species and the culture facilities

The prevalence of parasite based on host specie and culture facilities as highlighted in **Table 3** suggested that fish species as well as culture facilities were a major factor. The fish collected in the earthen ponds (8.67%) were significantly ($p < 0.05$) more infected than those from the concrete tanks (7.04%) (**Table 3**). However, the prevalence of Camallanus sp and capillary sp in O. niloticus collected in the concrete tanks were significantly ($p < 0.05$) higher compared to those from the earthen ponds. Moreover, Capillaria sp was the sole parasite with a significant high parasitic infestation rate ($p < 0.05$) in C. carpio captured from the concrete tanks.

Table 3 Prevalence of internal infection related to host species and culture facilities.

	Cyprinus carpio		**Total (N_3 = 593)**	**Clarias gariepinus**		**Total (N_6 = 692)**	**Oreochromis niloticus**		**Total (N_9 = 969)**	**Total**	
	EP (N_1 = 554)	**CT (N_2 = 39)**		**EP (N_4 = 493)**	**CT (N_5 = 199)**		**EP (N_7 = 937)**	**CT (N_8 = 32)**		**EP (N_{10} = 1984)**	**CT (N_{11} = 270)**
Acanthocephala											
Acanthocephalus sp.	8.84a	7.69a	8.77a	5.27a	2.01a	4.34b	2.88a	0.00a	2.79b	5.14a	2.59b
Nematods	4.87b	10.26a	5.23a	5.68a	3.02a	4.91a	2.56b	9.38a	2.79b	3.98a	4.81a
Camallanus sp.	1.81a	0.00a	1.69a	2.43a	0.50a	1.88a	0.32b	3.12a	0.41A	1.26a	0.74a
Eustrongylides sp.	0.90a	2.56a	1.01a	1.22a	0.50a	1.01a	1.17a	0.00a	1.14A	1.11a	0.74a
capillaria sp .	3.25b	7.69a	3.54a	1.01a	2.01a	1.30b	1.17b	6.25A	1.34b	1.71b	3.33a
Orientatractis sp.	0.36a	0.00a	0.34a	1.22a	0.00a	0.87a	0.00a	0.00a	0.00a	0.40a	0.00a
Total Endoparasites	12.45a	15.38A	12.65α	11.16A	5.03B	9.39β	5.12B	9.38A	5.26¥	8.67a	7.04b

EP: Earthen ponds; CT: Concrete tanks; N_{1-11}: Number of fish for each factor considered; N: Total number of fish; a, b, c: values with the same letters in the same column are not significantly different; A, B: Values with the same letters on the same row for the same host are not significantly different; α, β : Total values for each fish species are significantly different ($p < 0.05$).

Mean intensities based on culture facilities is shown in Figure 3. Culture facilities significantly ($p < 0.05$) influenced the parasite load. Indeed, it was higher in fish reared in concrete ponds ($p < 0.05$) than those in earthen ponds (Figure 4). Unlike for Camallanus sp. and Eustrongylides sp. whose intensities were invariable irrespective the culture facilities, whereas it was higher in earthen ponds but was not significant for Acanthocephalus sp. Orientatractis sp. was present only in Earthen ponds-with a parasite load >2. Indeed, Acanthocephalus sp. has a higher parasite load but with non-significative difference between culture facilities.

5.5 Parasite Infection and Mean Intensity According to the Fish Sex

The parasite infection rate as a function of fish sex is shown in Table 4. The overall rate of parasite infestation according to the fish sex was significantly ($p < 0.05$) higher in females than in males regardless of the fish species (Table 4). However, in C. carpio and Clarias gariepinus, the prevalence of Orientatractis sp was significantly ($p < 0.05$) higher in males (0.62%; 1.32%).

Table 4 Prevalence of gastrointestinal infection related to host species and sex in the West Region of Cameroon.

	Cyprinus carpio		**Total**	***Clarias gariepinus***		**Total**	***Oreochromis niloticus***		**Total**	**Total**		
	♀ (N_1 = 271)	♂ (N_2 = 322)	♂ + ♀ (N_3 = 593)	♀ (N_4 = 388)	♂ (N_5 = 304)	♂ + ♀ (N_6 = 692)	♀ (N_7 = 597)	♂ (N_8 = 372)	♂ + ♀ (N_9 = 969)	♀ (N_{10} = 1256)	♂ (N_{11} = 998)	♂ + ♀ (N = 2254)
Acanthocephala												
Acanthocephalus sp.	12.18a	5.90b	8.71a	6.44a	1.64b	4.34b	3.02a	2.42a	2.79b	6.05a	3.31b	4.84
Nematods	5.17a	5.28a	5.23a	6.19a	3.29a	4.91a	3.69a	1.34b	2.79b	4.78a	3.21a	4.08
Camallanus sp.	2.58a	0.09a	1.69a	3.35a	0.00b	1.88a	0.50a	0.27a	0.41A	1.83a	0.40a	1.20
Eustrongylides sp.	1.11a	0.93a	1.01a	1.03a	0.97a	1.01a	1.34a	0.81a	1.14A	1.19a	0.90a	1.06
capillaria sp.	4.06a	3.11a	3.54a	1.29a	1.32a	1.30b	2.01a	0.27b	1.34b	2.23a	1.50b	1.91
Orientatractis sp.	0.00a	0.62a	0.34a	0.52a	1.32a	0.87a	0.00a	0.00a	0.00a	0.16a	0.60a	0.35
Total Endoparasites	15.50 A	10.25B	12.65α	12.89A	4.93B	9.39β	6.20A	3.76B	5.26¥	10.27A	6.21B	8.47

N_{1-11} : Number of fish for each factor considered ; N: total number of fish; a, b, c: Values with the same letters in the same column are not significantly different; A, B: Values with the same letters on the same row for the same host are not significantly different ($p > 0.05$); α, β: Total values for each fish species are significantly different ($p<0.05$).

Parasite intensity related to fish sex is shown in Figure 5. As a whole, parasite intensity was significantly lower ($p < 0.05$) in females compared to males (Figure 6). Though, *Capillaria* sp. and *Acanthocephalus* sp . parasitic load were significantly higher ($p < 0.05$) in males than in females.

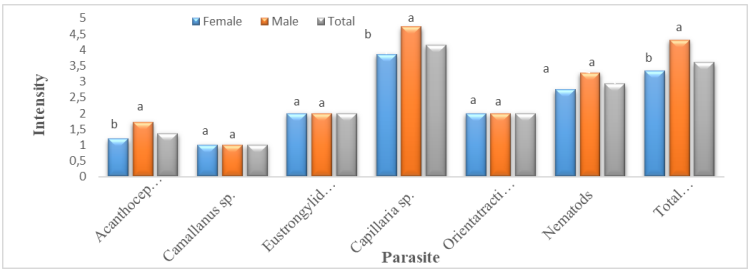

Figure 5 Intensity of the genera of endoparasites according to the sex of the host fish.

a, b: The bars assigned different letters differ significantly ($p < 0.05$), for a given parasite.

5.6 Effects of Fish Species, Sex, Size and Weight on The Prevalence of Helminths Associations

The effects of fish species, sex, size and weight on the prevalence of helminths associations are highlighted in Table 5. Globally, single infestations were about 32 times significantly more occurring than multiple infestations.

The prevalence of single (9.95%) and double (0.84%) associations was significantly higher ($p < 0.05$) in C. carpio compared to O. niloticus and C. gariepinus.

Unlike the fish size, sex and weight significantly ($p < 0.05$) influenced the prevalence of single and double associations. Indeed, female fish were more infected than males while <50g fish were mostly infected by acanthocephalans.

Table 5 Effects of fish species, sex, size and weight on the prevalence of single and double infections.

Host characteristics	Single infections			Double infections
	Acanthocephalus	Nematods	Total	Acanthocephalus + Nematods
Fish species				
O. niloticus	2.27(1.50–3.41)^{c}	2.68(1.84–3.90)^{a}	4.64(3.49–6, 16)^{b}	0.00(0.00–0.39)^{b}
C. Carpio	7.25(5.43–9.63)^{a}	4.38(3.01–6.35)^{a}	9.95(7.79–12.62)^{a}	0.84(0.36–19.58)^{a}
C. gariepinus	4.19(2.93–5.95)^{b}	4.19(2.93–5.95)^{a}	8.24(6.41–10.52)^{a}	0.00(0.00–0.55)^{b}
Fish sex				
Male	2.91(2.03–4, 14)^{b}	3.34(2.39–4.65)^{a}	5.57(4.30–7.18)^{b}	0.10(0.02–0.57)^{b}
Female	5.18(4.08–6.54)^{a}	3.82(2.89–5.03)^{a}	8.43(7.03–10, 11)^{a}	0.32(0.12–0.82)^{a}
Fish size classes (cm)				
Small	4.52(3.65–5.58)^{a}	3.85(3.05–4.84)^{a}	7.64(6.50–8.96)^{a}	0.27(0.12–0.65)^{a}
Large	2.82(1.66–4.77)^{a}	2.61(1.50–4.50)^{a}	5.21(3.53–7.65)^{a}	0.00(0.00–0.83)^{a}
Fish weight classes (g)				
X<50	6.90(5.39–8.80)^{a}	3.04(2.08–4.42)^{a}	8.89(7.16–10.98)^{a}	0.58(0.25–1.36)^{a}
50<X≤100	2.80(1.76–4.44)^{b}	4.12(2.81–6.01)^{a}	6.26(4.59–8.48)^{a}	0.00(0.00–0.63)^{a}
100<X≤150	1.05(0.41–2.67)^{b}	3.42(2.01–5.76)^{a}	4.47(2.81–7.05)^{a}	0.00(0.00–0.10)^{a}
150<X≤200	3.82(2.09–6.88)^{a}	4.58(2.64–7.83)^{a}	8.40(5.61–12.39)^{a}	0.00(0.000.14)^{a}
X>250	2.67(1.04–6.66)^{b}	3.33(1.43–7.57)^{a}	5.33(2.73–10.17)^{a}	0.00(0.00–2.5)^{a}
Total	4.17(3.42–5.08)^{a}	3.59(2.90–4, 44)^{a}	7.14(6.15–8.28)$^{\alpha}$	0.22(0.09–0.52)$^{\beta}$

5.7 Prevalence of Helminth Infections as Per the Target Organs

The prevalence based on the target organs is summarized in Table 6. Parasites were either encysted under the skin or found free in the gastrointestinal tract of the fish (Table 6). Whatever the fish species, the gastrointestinal tract was the most affected organ ($p < 0.05$).

Table 6 Prevalence of infections according to the location sites.

endoparasites	Cyprinus carpio		Clarias gariepinus		Oreochromis niloticus		Total (N=2254)	
	S	GI	S	GI	S	GI	S	GI
Acanthocephalus sp	0.0	8.26	0.0	4.48	0.0	2.37	0.0	4.57
Camallanus sp .	0.0	2.53	0.0	1.30	0.0	1.34	0.0	1.64
Eustrongyloides sp	1.18	0.0	0.87	0.0	1.14	0.0	1.06	0.0
capillaria sp .	0.0	0.34	0.0	1.88	0.0	0.31	0.0	0.80
Orientatractis sp .	0.0	0.34	0.0	0.72	0.0	0.00	0.0	0.31
Grand total	1.18	11.47	0.87	8.38	1.14	4.02	1.06b	7.32a

S: skin; GI: gastrointestinal tract; a, b: values with the same letters for a category (skin, gastrointestinal tract) in a row are not significantly different ($p > 0.05$).

6. Length-Weight Relationship and Condition Factor K Between Host Fish Parasitized And Non-Parasitized By Endoparasites

Overall, the length/weight relationship between parasitized and unparasitized specimens was non significantly higher ($p > 0.05$). However, C. gariepinus shows a difference ($p < 0.05$) between parasitized and non-parasitized specimens, as well as between all female specimens. The same observation was noted amongst the specimens collected in the dry season (Table 7). Concerning the condition factor, there was no significant difference between the non-parasitized fish and the parasitized fish. Nevertheless, the condition factor varied significantly ($p < 0.05$) between parasitized and unparasitized fish in C. carpio.

Table 7 Comparison of length-weight relationships and Fulton's condition factor (K) (g/cm3.) of endoparasites infected and uninfected fishes according to species, sex and season.

Variables		Standard length (cm) mean ± SD (min–max)	Mass (g) mean ± SD (Min–Max)	a Mean (95% CI)	b Mean (95% CI)	Length-weight relationship	Type of growth	R^2	Condition factor K (g/cm^3) mean ± SD (Min–Max)	F value (p-value)
O, niloticus	Uninfected ($N_1 = 906$)	14.30 ± 5.70 (6.00–30.00)	68.30 ± 48.85 (9.03–166.24)	0.0892 (0.0195–0.1589)	1,476 (1.4146–1.5375)	$W = 0.0892L^{1.476\alpha}$	negative allometry	0.7079	2.76 ± 1.40 (0.16-14.21)	6.622 (0.063)
	Infected ($N_2 = 50$)	12.90 ± 4.82 (7.00 – 27.50)	53.22 ± 33.96 (10.78–164.53)	0.1485 (-0.1824–0.479)	1.3818 (1.0928–1.6709)	$W = 0.1485L^{1.3818\alpha}$	negative allometry	0.6533	2.97 ± 1.46 (0.26–14.21)	
C, carpio	Uninfected ($N_3 = 518$)	16.21 ± 5.70 (7.50-43.10)	120.36 ± 90.71 (11.5–517.93)	-0.3020 (-0.4517–(-0.15)	1.9022 (1.7769–2.0275)	$W = -0.3020L^{1.9022\alpha}$	negative allometry	0.6329	2.93 ± 2.08 (0.06–19.76)	8.743(0.000*)
	Infected ($N_4 = 75$)	12.47 ± 4.45 (7.50–25.00)	77.41 ± 77.03 (17.25–300.00)	-0.7255 (-1.0007–0.45)	2.2847 (2.0300–2.5395)	$W = -0.7255L^{2.2847\alpha}$	negative allometry	0.8140	3.57 ± 1.79 (0.99–9.84)	
C, gariepinus	Uninfected ($N_5 = 627$)	21.77 ± 5.22 (9.80–36.50)	115.03 ± 63.90 (13.58–420.15)	0.8260 (0.7226–0.9294)	0.9046 (0.8224–0.9869)	$W = 0.8260L^{0.9046\alpha}$	negative allometry	0.4276	1.21 ± 1.20 (0.29–7.51)	12.659 (0.173)
	Infected ($N_6 = 65$)	19.40 ± 5.00 (10.5–28.0)	92.71 ± 53.14 (22.59–205.68)	0.0153 (-0.3756–0.406)	1.4889 (1.1795–1.7982)	$W = -0.3756L^{1.4889\beta}$	negative allometry	0.5949	1.31 ± 0.88 (0.61–6.48)	
females	Uninfected ($N_7 = 1,127$)	16.44 ± 6.37 (7.00–36.00)	98.75 ± 67.61 (15.05–517.93)	0.3766 (0.2976–0.4557)	1.2707 (1.2042–1.3372)	$W = 0.3766L^{1.2707\alpha}$	negative allometry	0.5556	2.89 ± 2.70 (0.06–16.44)	2112 (0.146)
	Infected ($N_8 = 129$)	14.94 ± 6.13 (7.00–28.00)	73.13 ± 54.34 (15.05–273.18)	0.0090 (-0.1776–0.195)	1.5277 (1.3656–1.6896)	$W = 0.0090L^{1.5277\beta}$	negative allometry	0.7326	2.81 ± 2.32 (0.34–14.58)	
Factors	Variables	Standard length (cm) mean ± SD (min–max)	Mass (g) mean ± SD (Min–Max)	a Mean (95% CI)	b Mean (95% CI)	Length-weight relationship	Type of growth	R^2	Condition factor K (g/cm^3) mean ± SD (Min–Max)	F value (p-value)
males	Uninfected ($N_9 = 936$)	(16.11 ± 6.18 (6.00–36.50)	91.22 ± 68.05 (9.03–420.15)	0.1050 (0.0184–0.1916)	1,484 (1.4112–1.5573)	$W = 0.1050L^{1.484\alpha}$	negative allometry	0.6302	2.83 ± 2.69 (0.30–19.76)	0.748 (0.387)
	Infected ($N_{10} = 62$)	15.82 ± 5.13 (8.00–26.50)	91.03 ± 76.53 (20.16–300.00)	-0.1429 (-0.6327–0.3470)	1.6788 (1.2655–2.0921)	$W = -0.1429L^{1.6788\alpha}$	negative allometry	0.5239	2.53 ± 2.00 (0.78–9.84)	

Dry season	Uninfected (N_{11} = 1,176)	16.46 ± 6.45 (7.00–43.10)	96.49 ± 65.47 (13.58–300.00)	0.2977 (0.2265–0.3688)	1.3439 (1.2843–1.4034)	$W = 0.2977L^{1.3439\alpha}$	negative allometry	0.6256	2.64 ± 2.13 (0.06–16.04)	0.393 (0.531)
	Infected (N_{12} = 102)	14.21 ± 5.74 (7.00–25.20)	65.94 ± 60.31 (20.23–300.00)	0.1586 (0.0517–0.2655)	1.4071 (1.3173–1.4969)	$W = 0.1586L^{1.4071\beta}$	negative allometry	0.6347	2.83 ± 2.25 (0.78–14.58)	
rainy season	Uninfected (N_{13} = 887)	15.819±6.57 (6.00 – 36.50)	89.01 ± 71.79 (9.03–517.93)	0.2312 (0.1338–0.3286)	1.3681 (1.2854–1.4507)	$W = 0.2312L^{1.3681\alpha}$	negative allometry	0.5438	2.81 ± 2.63 (0.16–14.58)	2259 (0.133)
	Infected (N_{14} = 89)	16.39 ± 5.74 (7.50 – 28.00)	93.84 ± 62.54 (15.30 – 273.18)	0.0050 (-0.3135–0.3234)	1.5699 (1.3040–1.8358)	$W = 0.0050L^{1.5699\alpha}$	negative allometry	0.6128	2.58 ± 2.18 (0.34–14.21)	
Total	Uninfected (N_{15} = 2063)	16.21 ± 6.50 (6.00–43.10)	93.28 ± 68.35 (9.03–517.93)	0.2624 (0.2037–0.3211)	1.3599 (1.3105–1.4093)	$W = 0.2624L^{1.3599\alpha}$	negative allometry	0.5860	2.79 ± 2.52 (0.06–14.58)	2250 (0.134)
	Infected (N_{16} = 191)	15.23 ± 5.83 (7.00–28.00)	78.94 ± 62.77 (15.30–300.00)	-0.0298 (-0.2144–0.1549)	1.5686 (1.4099–1.7276)	$W = -0.0298L^{1.5686\alpha}$	negative allometry	0.6676	2.72 ± 2.22 (0.34–14.58)	

*$N_{1–16}$: Number of fish for each factor considered; N: Total number of fish; * a and b: regression coefficient; R^2: determination coefficient; K: Condition factor; α, β: Total values for each fish species are significantly different ($p < 0.05$).*

7. Discussion

Helminths of three economically important fish species cultured in Cameroon was evaluated. In this study, an overall prevalence rate of 8.47% was recorded in Oreochromis niloticus, Clarias gariepinus and Cyprinus carpio species. This low rate of infection due to endoparasites s in agreement with the reports of Edema et al., 2008 and Ekanem et al., 2011 that assessed prevalence rate of 6.9% recorded in the Okhuo River and 3.3% in the Great Kwa River. However, it was lower compared to the results of Tchoumboue (1992); Donwa et al. (2012) in Cameroon with a prevalence of 26.8%. On the contrary, Ogonna et al. (2017) found a high prevalence (23.62%) in fish farms in Nigeria. The low infestation rate of these fish could be attributed to the sanitary state of the pond and their location relative to residential areas. These variations in the rate of parasitism could be attributed to the abiotic and biotic conditions of the environments where the studies were carried out (Thompson and Larsen, 2004). Moreso, Rohlenova et al. (2011) reported that unfavorable temperature can alter fish physiology, including immune function, favoring parasitic invasion. Similarly, the low rate observed could be due to a low proportion of intermediate hosts. The nematodes identified were localized in the gastrointestinal tract and in the subcutaneous tissues. The host specificity of nematodes is consistent with the findings of Ekanem et al. (2011) and Akinsanya et al. (2007). Kabata (1985) reported that Clinostomum (Acanthocephala) when ingested with undercooked fish, is capable of producing laryngopharyngitis which is an unpleasant inflammatory condition in humans. A genus of acanthocephalus was located in the gut of fish examined, which is consistent with the findings of Olurin and Somorin (2006) in fish from Kainji Lake and Owa River respectively. The prevalence was higher in the intestine than in other organs, which could be associated with the fact that most digestive activities take place in the intestine, thus constituting a feeding site for the parasites. It could be also attributed to the favourable nutritional advantage presented by the hosts' intestine to the parasites; this assertion agrees with the findings of Solomon et al., (2018), Agbabaka et al., (2017), Kawe et al., (2016). This situation could result in the release of parasitic ova/cysts into the food particles. The high prevalence of acanthocephalan and nematode parasites can be attributed to the presence of a suitable intermediate host (Nmor et al., 2004), the trophic link with fish (Lagrue et al., 2011) and the efficiency of the transmission of the parasite in the fish host (Iyaji et al., 2009).

Despite the fact that a low level of parasitic infection and intensity were recorded, the factors associated with endoparasites were evaluated because of their pathogenic effect on fish and a zoonotic tendency of some identified parasites.

In the present study, females were heavily infected with endoparasites than males. This disagrees with the report studies of Ogonna et al. (2017). The higher overall parasite prevalence observed in females may suggest a difference in ecological requirements between males and females (Iyaji et al., 2009) and a greater susceptibility of ovigerous females to the parasite (Simkova et al., 2008). Emere and Egbe (2006) also reported that this may possibly be due to difference nutritive both by amount or excellence of nourishment consumed and as an outcome of dissimilar amounts of struggle/fight to infestation.

The prevalence of internal parasites was also evaluated based on different length and weight (age) categories. A higher infection rate was reported in fish with low body weight. it implies that the activities of intestinal parasites contribute to the decrease in body weight, which is similar to the findings of Oniye et al . (2004) and Ogonna et al. (2017). Indeed, the number of parasites increases with the length of the fish and suggests that the augmentation in the number of parasites could be due to the accumulation of parasitic larvae as the fish ages (Musa et al., 2007). Endoparasites were found in the sampled species, which is in agreement with the results of Awharitoma and Okaka (2004). There was a significant difference ($p<0.05$) in the infection rate among the fish species sampled, with C. carpio recording the highest prevalence rate. Variations in the prevalence of infection at different locations have been attributed to factors such as the availability of intermediate hosts and host susceptibility to infection (Ashade et al., 2013). In addition, unhygienic practices of fish farmers encourage helminth contamination of agricultural products (Ani et al., 2015; Ani et al., 2016).

Parasite intensity was very low (less than 10) according to the classification of Bilong Bilong and Njine (1998). However, it was higher in O. niloticus regardless of the type of endoparasite considered. This could be due to intrinsic factors specific to hosts and parasites (Bush et al., 1997 and Sasal et al., 1997).

The parasite load was statistically influenced by the length and weight of fish suggesting that they can be considered as risks factors. Indeed, the distribution of parasite intensity according to size classes shows the existence of heterogeneity in the colonization of fish species. Parasite intensity was positive and very significantly correlated with fish size. This shows that this parasitism evolves according to the size of the fish, as several authors have already pointed out (Tchoumboué, 1992; Gaddy and Philip, 2004; Kassi, 2009; Mathieu et al., 2011). also, the parasite load was higher in larger fish. The increase in parasite intensity in relation to the size of the host could be linked not only to the accumulation of parasites during its life but also to the change in diet (Poulin, 2006). This supposes that the infection is continuous throughout life, in correlation with feeding behavior and the quantity of food ingested. These factors favor the encounter between fish and potential intermediate hosts of nematodes, cestodes, digeneans and acanthocephalans (Ali, 2009).

A higher parasite intensity was recorded in males compared to females. This situation can be explained by the fact that males feed more than females, are more in contact with intermediate hosts and spend more time in the rearing environment. They are therefore more likely to encounter endoparasites than their female counterparts (Aloo, 2002; Idris et al., 2013). These results are contrary to those obtained in Nigeria by Ibiwoye (2004) in C. gariepinus where the females carried significantly ($p < 0.05$) more larvae of Eustrongylides africanus than the males.

A bispecific parasite association has been observed in fish species. Single infections were the predominant cases, but multiple infections were also common in this study. This situation can be explained by the fact that the farmed environment supports several parasites species thereby exposing the host to simultaneous infection with many of them. This also demonstrates the absence of interspecific exclusion of these parasites in the fish species examined. The presence of one parasite and its activity within the host weaken the resistance which makes concurrent infection feasible. The presence of Acanthocephalus sp. capillaria sp. and Eustrongylides sp. which would have a zoonotic tendency enhances the emergency of developing adequate prophylactic measures

in the establishment of a fish farm.

Length-weight relationship is an important tool that provides information on fish growth and profile (Ighwela et al., 2011) as well as measures of other zootechnical parameters such as productivity. Its parameters (a and b) have wide applications in fish biology and fisheries management. Weight varies with fish length while fish length is a major indicator of production efficiency (Ghorbani et al., 2012). Variations in b-values were attributed to variation in sample size, life stages, difference in growth, change in physiological conditions of fish, gonad development, sex, environmental conditions, physicochemicals of the environment and to other environmental factors such as food and space (Prasad and Ali, 2007; Jobling, 2008; Hossain et al., 2016). In addition to a slight decrease in the weight of parasitized specimens, this study showed a statistically significant difference between the length-weight relationships of parasitized and unparasitized specimens. This leads to a conclusion that parasitism therefore has an influence on fish growth and weight. These findings contradict those of Hajji et al. (1994) and Zouhir et al. (2010) who found no difference in biological parameters between parasitized and non-parasitized specimens.

Overall, the average condition factor value obtained for uninfected fish was significantly higher than that for infected fish. Thus, unparasitized fish are in better health than parasitized ones. These results are contradictory with the work of Zouhir et al. (2010). Parasitism therefore has a negative impact on the zootechnical performance of fish farmed in the study area.

Insufficient evidence of a negative effect of parasitism caused by endoparasites on the condition index of the considered fish was noted. Such an apparent lack of parasite effect on host growth and condition could be explained by the host compensating for higher rates of energy loss, by feeding more than unparasitized specimens (Östlund -Nilsson et al., 2005). In addition, this could be attributed to the low prevalence and intensity observed in the area of study. However, the pathogenic effect is rarely caused by a single specie of parasite (Fomena et al., 1996). Indeed, the migration of parasites can cause tissue lesions in fish, which constitutes entry points for secondary pathogens (fungi, bacteria and viruses) that can lead to massive mortality, especially in young fish (Thiéry and al., 2003). It would be advisable to consider studies in the fungal, bacteriological or even virological level. Despite the fact that a low prevalence is recorded, these fish should be properly cooked to avoid ingestion of parasites by fish consumers due to the zoonotic tendency accorded to Acanthocephalus sp. Capillaria sp. and Eustrongylides sp. parasites.

8. Conclusion

The current survey display a low occurrence of gastrointernal parasitic invasions and shown parasites of zoonotic importance such as Eustrongylides sp., Contracaecum sp. and Acanthocephalus sp. These observations can be used as reference line parasitic data for upcoming research to safeguard and improve the environmental potential of fish ponds. Adequate measures should thus be taken into consideration, because the silent spread of these infections could be a result of poor managerial condition. This study recommends that consumption of correctly roasted fish serve as precautionary measures to possible zoonotic parasite infestation. Further researches should be done to highlight on the status of contamination and to find out the exact correlation between contamination, toxic waste and parasitism in fish ponds.

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Conflict of interest

The authors declare no conflict of interest.

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