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Checklist, occurrence and associated risk factors of parasitic infections of potential farming fish species from the lower course of River Nkam, Cameroon

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ABSTRACT: A cross-sectional study was conducted from April to October 2023 along the downstream of River Nkam in Yabassi locality (Littoral-Cameroon). The objective was to determine parasite fauna, the prevalence, abundance, mean intensity and risk factors of parasitic infections in wild freshwater fishes as for their control during their successful domestication and conservation. A total of 151 fishes comprising 43 *Ctenopoma petherici,* 31 *Clarias jaensis, 21 Parachanna obscura,* 25 *Chrysichthys nigrodigitatus* and 31 *Oreochromis niloticus* randomly captured from the River Nkam were used for the determination of the parasitological indexes. The results showed an overall high prevalence of multiple infections of 72.85% of all the fish species by five groups of parasites ($p<0.0001$) namely monogeneans (61.53%), trematodes (18.54%), myxosporeans (19.90%), cestodes (2.83%) and nematodes (8.72%). Besides, the abundance and mean intensity of monogeneans infection were either low or average and not influenced by the fish species. The significance of the effect of the fish sex, size and weight on the infection by monogeneans depended on fish species. Fishes from the Nkam river should be quarantined and treated against parasites before farming.

KEYWORDS: Parasites, fish, infection, parasitological indexes, River Nkam, Yabassi.

1 INTRODUCTION

Fish account nearly for 51% of animal proteins intake in Cameroon and are highly appreciated by many households compared to others animal protein sources because it is cheaper and has white flesh. The average fish and meat consumption of 17.9 and 13.07 kg per person per year respectively have been estimated in the country (FAO, 2016) [1]. Though there are increasing demands for fish with the rapid population growth in Cameroon, many factors including climate change, illicit fishing and overfishing have constrained the attainment of optimum fish production levels in the country (Fonkwa *et al*., 2022) [2]. The national annual production of 335, 000 tons is far short of estimated demand of 500,000 tons/year and has caused supplementary yearly importation of about 180,000 tons of fish (MINEPIA, 2018) [3].

Boosting the national production levels, farming of better adapted and performant native fish species and achieving youth employment in the fish sector have been proposed as strategic solutions to eliminate the deficit (Tomedi *et al.,* 2014) [4]. However, intensification of fish production is usually limited by diseases and particularly parasitic infections (Nounagnon *et al*., 2016) [5]. Crowded culture conditions, high temperature and slow water flow in farming process favors parasite multiplication and infestations (Farman *et al.,* 2015) [6] and early detection of fish parasites in fish farms is vital for preventing outbreaks of diseases. Parasitic diseases of fish in natural environments and cultured fish cause great economic impact and are of major

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public health concerns particularly in the tropics (Amare *et al*., 2014) [7]. Myxosporeans affect growth, reproduction and are the cause of massive deaths in fish farms (Longshaw *et al*., 2010) [8] and the health of immunodepressed persons has been affected following consumption of myxosporeans infected fish (Hessen and Zamzame, 2004) [9].

There is scare information on the distribution and suitable conditions for parasitic infections of fish in some wild environments and cultured fish fish in Cameroon (Nack *et al*., 2018 [10], 2020 [11]; Lekeufack *et al*., 2019 [12]; Fonkwa *et al.,* 2021 [13], 2022 [2]). Though the River Nkam provides suitable habitats for multiplication and growth of various wild fish species and socioeconomics livelihood of the riverine communities through fishing and harvesting of other edible aquatic animals, there is dearth of information on the epidemiology of diseases of aquatic animals and their socioeconomics impact on the dynamics of edible aquatic animals in this river. Accurate knowledge and effective control strategies of fish diseases are vital for successful domestication of dietary wild aquatic animals include the freshwater fish species.

In this context, this study was carried out to determine the parasite fauna, the occurrence (prevalence, abundance, mean intensity) and risk factors of parasitic infections in socioeconomically important and edible wild fish captured in River Nkam in Cameroon.

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

A cross-sectional study was carried out from April to October 2023 of randomly selected fishes captured in River Nkam at Yabassi and Bodiman villages (4°27'- 4°30'North Latitude; 9°57'- 10° 20'East Longitude) of Littoral Region of Cameroon. The study sites are at an altitude of about 15.5m above the sea level and have sedimentary soil with a pH ranging from 6.5 to 8.5. The climate is of the subequatorial type with a dry season (November to March) and a rainy season (April to end October) with an annual average temperature varying from 25 to 35°C and the rainfall of about 1364.4 mm (Tomedi *et al*., 2014 [4]).

2.2 SELECTION OF FISH SAMPLE FOR THE STUDY

A total of 151 fishes randomly selected at dawn (sunrise) from among fishes captured at night by local fishermen using mesh gill nets were purchased and used in this study. The abdominal region of each selected fish specimen was punctured to improve conservation of internal organs and immediately transported in cool boxes to the Laboratory of Parasitology and Ecology of the University of Yaoundé I-Cameroon and stored at 4°C for parasitological examination within 12 hours of arrival.

The sexe of the fish were determined by pressing the abdomen and when the fish were dissected and the gonads inspected using previously described procedures (Akombo *et al*., 2013 [14]; Mbakane *et al*., 2010 [15]). Briefly, pressing the abdomen of some adult fish specimens caused the release of whitish milk for males and eggs for females. Upon dissection of some adult female samples, eggs were readily seen swollen in the paired ovaries, while the testes were typically flattened and elongated, whitish and non-granular in appearance in adult male samples.

The fish species were determined with the aid of previously described keys (Olaosebikan and Raji, 2004 [16], Stiassny *et al*., 2007 [17]) and were composed of *Ctenopoma petherici, Clarias jaensis, Parachanna obscura, Chrysichthys nigrodigitatus* and *Oreochromis niloticus.*

2.3 PARASITOLOGICAL EXAMINATION OF FISHES

Each fish sample was visually examined for any malformation or abnormality using standard procedures (Ali, 2009 [18], Noga, 2010 [19], Farman *et al.,* 2015 [6]). The standard length (distance from the anterior end of the snout to the posterior end of the last vertebra of the fish) was measured and the samples grouped in four size classes using the modified Yule formula (Lekeufack *et al*., 2019 [12]). The weight of each sample was determined using an electronic Sartorius balance and categorized into four weight classes (Table 1).

The fins, eyes and skin were examined at 10X lens of a stereomicroscope (Wild Heerbrug M2G17 brand) and the metacercaria and whitish myxosporidia cysts counted. The fish samples were dissected dorso-ventrally and sexed by examination of their gonads as previous described (Assefa and Abuna, 2018 [20], Manbe *et al*., 2020 [21]). The body cavity, stomach and other visceral surfaces were examined for parasites. The liver, gonads, heart, kidneys, gall bladder and gill filaments were rinsed in petri dishes then bathed with 0.7% NaCl solution for recovery of parasites which were fixed in glycerine for further identification. Monogeneans on the filaments of gill were dislodged using a needle (Nack *et al*., 2020 [11]) while

myxospores on the kidneys, spleen, liver and gonads were crushed in a drop of distilled water between slide and cover glass (Fonkwa *et al.,* 2021 [13]) for identification as previously described. The identification of the ectoparasites was based on distinctive morphological features using reference identification keys and pictorial guides for taxa of fish parasites (Yanong, 2002 [22]; Chandra, 2004 [23]; Pouder *et al*., 2005 [24]). An infected fish sample was coded as 1 and uninfected as 0.

Table 1. Community structure of fishes sampled from the lower course of River Nkam

Fish species	Sex		Total	MSL (mm)	Mean weight (g)
	♂	♀:			
Ctenopoma petherici	20	23	43	98 (65 - 460)	50 (43- 403)
Chrysichthys nigrodigitatus	17	14	31	121 (58-510)	41(12 - 380)
Parachanna obscura	9	12	21	76 (80-433)	52 (28 -398)
Oreochromis niloticus	14	11	25	90 (40 - 280)	34 (18 -302)
Clarias jaensis	15	16	31	39 (52-413)	43 (14-208)
Total	75	76	151	84 (59- 419)	44 (23 -338)

MSL: Mean Standard Length; (): minimum – maximum values; ♂: male; ♀: female

2.4 Parasitological Indexes Studied And Data Analysis

The following parasitological indexes: the prevalence, abundance and the mean intensity of infection were calculated according to Bush et *al*. (1997) [25]. The prevalence (Pr) or infection rate defined as the percentage of fish infected by a parasite taxon was classed as very low (Pr < 10 %), low (10 % ≤ Pr ≤ 50 %) or high (Pr > 50 %) corresponding respectively to rare/satellite, secondary/intermediate and frequent/core parasites as previously described by Valtonen *et al*. (1997) [26]. The abundance (A) or mean load was the ratio between the number of cyts or individual worms of a given parasite taxon infecting a given fish species and the total number of fishes examined. The mean intensity (I) was the average number of cysts or worms of a particular parasite taxon among the infected members of fishes found in the sample divided by the number of fishes infected with that parasite. Both the abundance and mean intensity were categorized as very low (A or I <10), low (10 ≤ A or I ≤50), average (50 <A or I ≤ 100) or high (A or I > 100) as previously described by Bilong and Njiné (1998) [27].

The obtained data was submitted to descriptive statistics using Graph Pad Prism 5 software. The association between the epidemiological indexes and risk factors such as host sex, size and weight was measured using the Chi-square (X^2) test. The relationships between the risk factors, abundance and mean intensity were obtained from pooled data using analysis of variance (ANOVA). The significant level was set at $p < 0.05$.

3 Results

3.1 Parasitic Fauna Of Fishes In River Nkam

A total of five parasitic groups of parasitic fauna of fishes (Figure 1) composed of helminthes (monogeneans, nemotodes, trematodes, cestodes) and protozoa (myxosporeans) were recorded in the study. Lymphocytosis was observed in *Chrysichthys nigrodigitatus* specimen (Figure 1c).

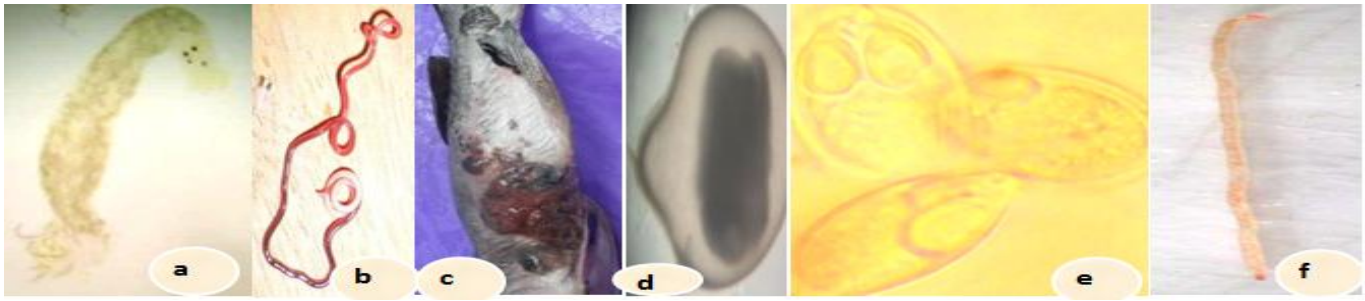

Fig. 1. Photograph of parasites groups and lymphocytosis recorded in fishes captured from River Nkam, Cameroon
a: Monogenean b: Nematode; c: Lymphocytosis in Chrysichthys nigrodigitatus; d: Trematode metacercaria; e: Myxospores f: Cestode

The present study showed that all examined fish species were infected by the five groups of parasites (Table 2) recorded except *C. petherici* and *O. niloticus* that did not harbor tapeworms (cestodes).

Table 2. Distribution of parasitic groups according to fish species captured in River Nkam, Cameroon

Fish species	Parasite groups				
	Monogeneans	Trematodes	Cestodes	Nematodes	Myxosporeans
C. petherici	+	+	-	+	+
C. nigrodigitatus	+	+	+	+	+
P. obscura	+	+	+	+	+
O. niloticus	+	+	-	+	+
Clarias jaensis	+	+	+	+	+

+ = present; - = absent

3.2 PREVALENCE OF PARASITIC INFECTIONS OF FISH SPECIES CAPTURED FROM RIVER NKAM

Overall, 110 out of 151 examined fishes were infected (72.85%, (65.26 – 79.31)) with significant difference (X^2=46.45; p < 0.001) observed between species (Figure 2). C*larias jaensis* showed a low prevalence (48.38%) compared to the others fish species with the highest value (96.76%) recorded for *C. nigrodigitatus.* The difference between species was statistically significant (X^2=46.45; p < 0.001).

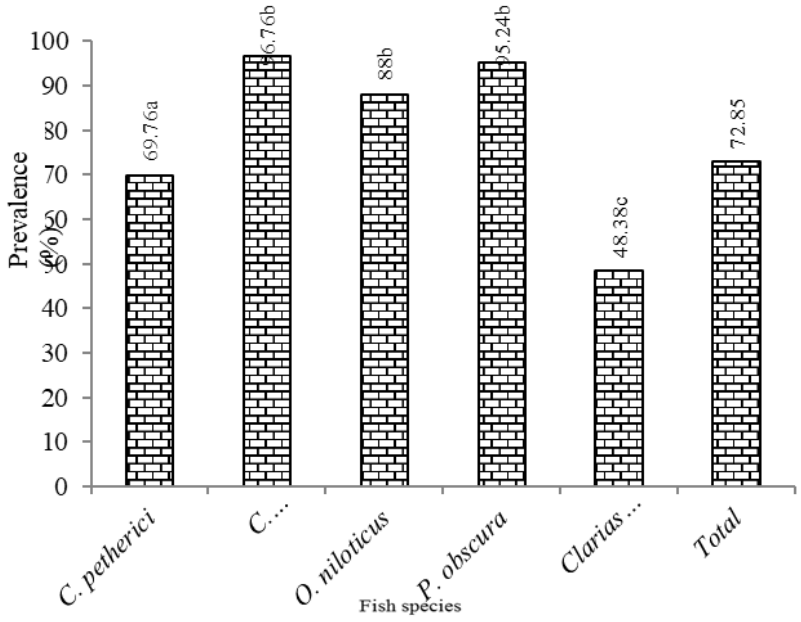

Fig. 2. Prevalence of parasitic infections of fish species captured from River Nkam, Yabassi, Cameroon. a, b; c: Values with different letters differ significantly (p < 0.001)

3.3 PREVALENCE OF PARASITIC INFECTION OF FISH SPECIES ACCORDING TO THE PARASITIC GROUPS

The highest prevalence was recorded with monogeneans (61.53%) compared to the other parasite types (X^2=186.50; p<0.0001) irrespective of the fish species (figure 3). The prevalence of monogeneans was significantly influenced (X^2=46.45; p<0.0001) by the fish species and was about three times more (p<0.001) than trematodes (18.54%) and myxosporeans (19.90%).

Cestodes (2.83%) and nematodes (8.72%) recorded a very low prevalence (Pr < 10 %). Myxosporeans were the most prevalent (10.00%) parasitic group after monogeneans in *C. petherici*. For *Clarias jaensis,* the prevalence of myxosporeans infection was two times higher than that of monogeneans (figure 3).

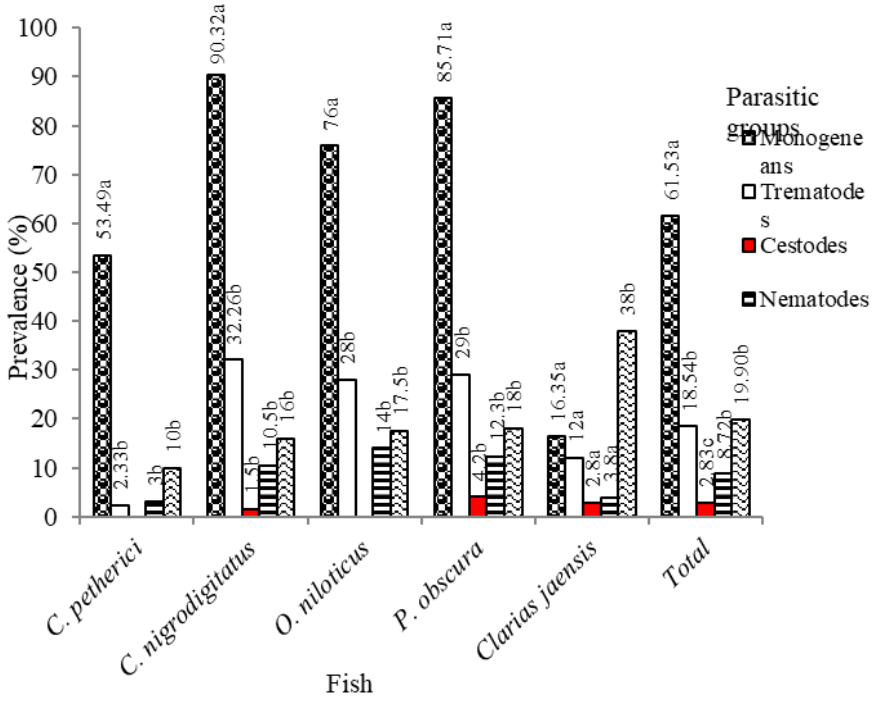

Fig. 3. Prevalence of parasitic group infections of fish species captured from River Nkam, Yabassi, Cameroon. a, b; c: For a fish species, values with different letters differ significantly (p < 0.05)

The prevalence of monogeneans (Table 3) was non-significantly higher (p> 0.05) in male than female fishes unlike female (100%) *O. niloticus* that showed significantly higher (X^2=4.94; p = 0.01) rates compared to the males (57.14%).

Table 3. Prevalence of monogenean infections of fish species according to sex captured from River Nkam, Yabassi, Cameroon

Fish species	Fish sex		Total	X^2	p
	Male	Female			
C. petherici	60 (12)	47.82 (11)	53.49 (23)	0.03	0.85
C. nigrodigitatus	94.12 (16)	85.71 (12)	90.32 (28)	0.62	0.43
O. niloticus	57.14 (8)	100 (11)	76 (19)	4.94	0.01*
P. obscura	88.88 (9)	83.33 (12)	85.71 (18)	0.13	0.71
C. jaensis	20 (3)	12.50 (2)	16.13 (5)	0.32	0.57
Total	62.67 (47)	60.53 (46)	61.59 (93)	2.81	0.09
X^2	6.03	9.43			
P	0.20	0.051			

*(): Number of infected fish *: Significant (p < 0.05)*

Monogeneans infected all size classes of fishes except *O. niloticus* exceeding 400mm length which showed no parasite infection. Though size did not affect infection rates, the prevalence seemed to increase with fish size.

Table 4. Prevalence of monogenean infections of fish species according to size captured from River Nkam, Yabassi, Cameroon

Fish species	Size classes (mm)				x^2	p
	[100-200[	[200-300[	[300-400[	≥400		
C. petherici	42.86(3)	40 (8)	69.23(9)	100 (3)	5.68	0.12
C. nigrodigitatus	87.50(14)	100 (5)	83.33(5)	100 (4)	1.44	0.69
O. niloticus	66.67(2)	84.61(11)	66.67(6)	/	1.10	0.57
P.obscura	81.81(9)	85.71(6)	100 (1)	100 (2)	0.63	0.88
C. jaensis	9.09(1)	12.50(2)	50 (1)	50 (1)	3.95	0.26
Overall	57.59(29)	64.56(32)	73.85(22)	70(10)	2.36	0.50
x^2	7.35	6.99	-	-		
P	0.12	0.14	-	-		

(): Number of infected fishes /: No infected -: No statistically computable

The prevalence of monogenean infections significantly increased ($p<0.05$) with weight for *C. petherici* and *C. jaensis* (Table 5).

Table 5. Prevalence of monogenean infections of fish species according to weight captured from River Nkam, Yabassi, Cameroon

Fish species	Weight classes (g)				x^2	p
	[0-100[	[100-200[	[200-300[	≥300		
C. petherici	43.30(18)	100(5)	-	-	8.06	0.04*
C. nigrodigitatus	-	-	90 (18)	88.89(10)	2.78	0.42
O.niloticus	90.90(10)	60(6)	66.67(2)	100(1)	3.20	0.36
P.obscura	81.82(9)	85.57(5)	100(3)	100(1)	0.63	0.88
C. jaensis	7.69 (2)	58.35(3)	-	-	8.92	0,03*

*(): Number of infected fishes *: Significant ($p < 0.05$) -: No infected*

3.4 Relative Abundance And Mean Intensity Of Monogenean Infections

Overall, monogeneans were the core parasites recorded in this study and their prevalence and intensity of significantly higher ($P<0.0001$) compared to trematodes, myxosporeans, cestodes and nematodes irrespective of the fish species.

Globally, the abundance of monogeneans showed no significant ($p > 0.05$) difference between fish species (Figure 4).

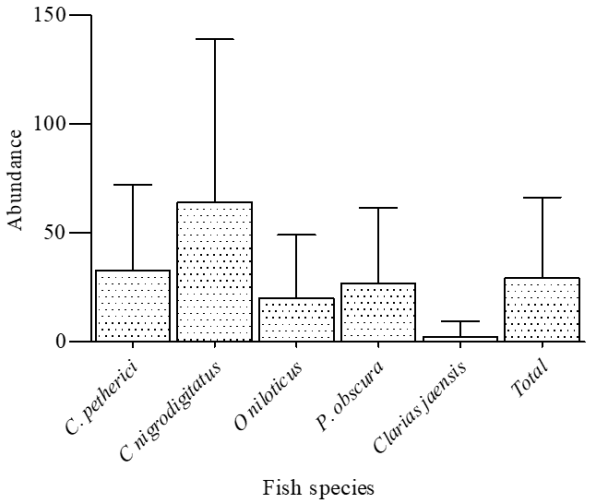

Fig. 4. Relative abundance of monogenean infections on fish species captured from River Nkam, Yabassi, Cameroon

Also, the mean intensity of monogeneans' (Figure 5) was 40.97 ± 43.58 was not affected by the fish species (F = 0.11; p = 0.02) and ranged from 13.20±18.02 (*C. jaensis*) to 60.00 ± 37.50 (*Chrysichthys nigrodigitatus*).

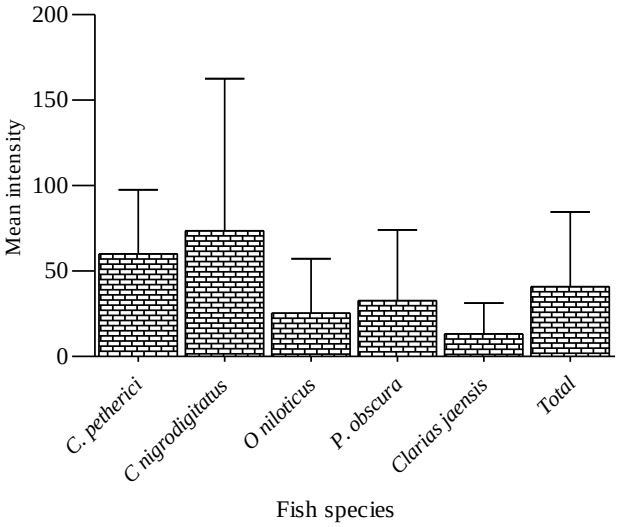

Fig. 5. Mean intensity of monogeneans on fish species captured from River Nkam, Yabassi, Cameroon

The relative abundance of monogeneans was not affected (p>0.05) by the fish sex (Table 6). The relative abundance in *C. petherici* and C*. jaensis,* was two times higher in males than in females contrary to the females harboring more worms in *C. nigrodigitatus, O. niloticus* and *P. obscura*.

Table 6. Relative abundance of monogenean infections on fish species according to sex captured from River Nkam, Yabassi, Cameroon

Fish species	Fish sex		F	p
	Male	Female		
C. petherici	42.05±48.57(20)	23.44±30.84(23)	2.31	0.14
C. nigrodigitatus	40.79±40.81(17)	87.53±108.99(14)	2.30	0.14
O.niloticus	12.79±28.17(14)	27.46±31,01(11)	1.53	0.22
P.obscura	20.11±18.03(9)	34.00±50.77(12)	0.61	0.44
C. jaensis	3.00±10.80 (15)	1,31±4.11(16)	0.38	0.60

Abundance ± Standard Deviation (number of examined fishes)

The result on sex related mean intensity of monogeneans infection (Table 7) showed that the females of *C. petherici, P.obscura, C. jaensis* and *O. niloticus,* harbored more worms contrary to *C. nigrodigitatus.* No significant difference was observed between both sexes except in *C. petherici* (F = 4.75; p = 0.04) at which parasites burden was higher in females than in males. Irrespective of sex, the lowest mean intensity was observed with *C. jaensis* unlike *C. nigrodigitatus* and *C. petherici* where the males (93.00±110.14) and females (76.46±39.86) respectively recorded the highest values.

Table 7. Mean intensity of monogeneans infections on fish species according to sex captured from River Nkam, Yabassi, Cameroon

	Male	Female		
C. petherici	44.92±29.15(12)	76.46±39.86(11)	4.75	0.04*
C. nigrodigitatus	93.00±110.14(16)	47.58±40.20(12)	1.84	0.18
O. niloticus	22.37±35.05(8)	27.45±31.04(11)	0.11	0.74
P.obscura	22.23±17.51(8)	40.80±53.31(10)	0.85	0.37
C. jaensis	10.50±13.43(3)	15.00±23.38(2)	-	-

*Intensity ± Standard Deviation (number of infected fishes) *: Significant (P<0.05) -: no computable*

The effect of the fish size classes on the relative abundance of monogeneans is shown in Table 8. The relative abundance was significantly ($p < 0.05$) affected by the size for *P.obscura, C. jaensis* and *C. petherici,* contrary to *C. nigrodigitatus* and *O. niloticus.*

Table 8. Relative abundance of monogenean infections on fish species according to size captured from River Nkam, Yabassi, Cameroon

Fish species	Size classes (mm)				F	p
	[100-200[	[200-300[	[300-400[	≥400		
C. petherici	22.14±29.72(7)	19.50±33.72(20)	46.85±41.51(13)	75.33±69.15(3)	2.78	0.05*
C. nigrodigitatus	57.87±82.26(16)	113±154.92(5)	45.33±44.78(6)	74±45.13(4)	0.62	0.60
O. niloticus	8.33±13.57(3)	29.62±37.68(13)	7.89±10.82(10)	-	1.75	0.19
P.obscura	12±12.02(11)	32.14±26.26(9)	27±0(1)	102.50±111.01(2)	4.41	0.01*
C. jaensis	0.09±0.30(13)	1.31±4.99(15)	21±29.69(2)	1±1.41 (1)	11.60	0,004*

*Abundance ± Standard Deviation (number of examined fishes) *: Significant (p < 0.05) -: No infected*

Overall, the size of fish size had no effect ($p>0.05$) on the mean intensity of monogeneans (Table 9) except for P*arachanna obscura* which showed significantly ($F = 3.67$; $p = 0.03$) higher mean intensity in older and larger fish (SL ≥ 400mm) compared to other size classes.

Table 9. Mean intensity of monogeneans infections on fish species according to size captured from River Nkam, Yabassi, Cameroon

Fish species	Size classes (mm)				F	P
	[100-200[	[200-300[	[300-400[	≥400		
C. petherici	51.67±19.04(3)	48.75±38.17(8)	67.67±31.62(9)	75.33±69.15(3)	0.55	0.65
C. nigrodigitatus	66.14±89.96(14)	113.00±154.92(5)	54.40±43.48(5)	74.00±45.13(4)	0.41	0.74
O. niloticus	12.50±16.26(2)	35.00±38.9(11)	11.83±11.46(6)	/	1.23	0.31
P.obscura	14.67±11.69(9)	37.50±24.22(6)	27.00±00.00(1)	102.50±111.02(2)	3.67	0.03*
C. jaensis	-	-	-	-	-	-

*Intensity± Standard Deviation (number of infected fishes) *: significant (p < 0.05) /: No infected -: No considered*

Overall, the relative abundance of monogeneans according to fish (Table 10) was significantly ($p < 0.05$) influenced by weight of fish except for *O. niloticus* and *C. nigrodigitatus*.

Table 10. Relative abundance of monogenean infections on fish species according to weight captured from River Nkam, Yabassi, Cameroon

Fish species	Weight classes(g)				F	p
	[0-100[	[100-200[	[200-300[	≥300		
C. petherici	14.29±24.65(14)	33.63±38.42(24)	91±53.86(5)	9±0 (3)	4.86	0.006*
C. nigrodigitatus	69.05±104.49(20)	63.67±45.03(6)	49.50±16.26(2)	65.67±74.40(3)	0.03	0.99
O.niloticus	23.72±28.63(11)	18.10±36.66(10)	9.33±13.65(3)	11±0(1)	0.20	0.89
P.obscura	12±12.02(11)	28.50±26.76(6)	35±16.52(4)	181±0 (2)	26.81	0.0001*
C. jaensis	0.06±0.24(18)	0.13±0.35(8)	20.67±21(3)	1±1.41(2)	11.60	0.0001*

*Abundance± Standard Deviation (number of examined fishes) *: significant (p <.05)*

Though, weight of *P. obscura* significantly ($p < 0.05$) affected by the mean intensity of monogeneans infection, weight did not influence the mean intensity of monogeneans on the other fish species in this study (Table 11).

Table 11. Mean intensity of monogeneans infections on fish species according to weight captured from River Nkam, Yabassi, Cameroon

	Weight classes (g)				F	p
Fish species	**[0-100[**	**[100-200[**	**[200-300[**	**≥300**		
C. petherici	53.83±24.68(18)	71.50±50.39(12)	-	-	1.83	0.17
C. nigrodigitatus	/	/	76.72±99.99(18)	98.50±33.26(10)	0.12	0.94
O. niloticus	26.10±29.01(10)	30.17±44.52(6)	14.00±15.56(2)	11.00±00.00(1)	0.18	0.91
P.obscura	14.67±11.69(9)	34.20±25.53(5)	35.00±16.52(3)	181.0±00.00(1)	27.41	0.0001*
C. jaensis	-	-		-	-	-

*Intensity ± Standard Deviation (number of infected fishes) *: significant (p < 0.05) /: No infected -: No considered*

4 DISCUSSION

The parasitic fauna of fishes from the lower course of the Nkam River composed of five groups (monogeneans, nemotodes, trematodes, cestodes, protozoa) had been observed in freshwater fishes worldwide. Indeed, monogeneans, crustaceans (copepods, leaches) have been identified in cultured common carp (*Cyprinus carpio)* (Farman *et al.,* 2015 [6]) as well as protozoa (ciliates, myxosporeans) and monogeneans in carp fingerlings of *Catla catla, Cirrhinus mrigala, Labeo rohita, Channa punctatus,* and *Cyprinus carpio* (Habib *et al.,* 2019 [28]) in Pakistan. Nematodes (*Contracecum* spp., *Camallanus* spp., *Eustrongylides* spp.), trematode (*Clinostomum* spp.), cestodes (*Ligula intestinalis, Proteocephalus* spp.) in the body cavities and gastrointestinal tracts of *Oreochromis niloticus* (Nile Tilapia), *Clarias gariepinus* (African Catfish) and *Cyprinus carpio* (common carp) have been reported in Lake Lugo (Hayke) in Northeast Ethiopia (Amare *et al.,* 2014 [7]). Also, trematode (*Clinostomum* sp.), nematodes (*Cithariniella petterae, Procamallanus laeviconchus, Synodontisia thelastomoides*) and cestodes (*Stoeksia pujehuni* and *Lytocestus* sp.) have been detected on fishes *Synodontis schall* and *Synodontis nigrita* in South Benin (Dougnon *et al*., 2012 [29]). In Cameroon, several species of monogeneans (Nack *et al*., 2018 [10]; Nack *et al*., 2020 [11]) and myxosporeans (Fonkwa *et al.,* 2020a [30]) have been identified in fishes from natural and controlled environments, as well as nematodes (*Eustrongylides* spp*., Contracaecum* spp.) in *Clarias gariepinus* and *Clarias jaensis* captured from River Nkam (Domwa, 2012 [31]).

The scarcity of acanthocephalans in the fishes examined in this study (done at the lower course of River Nkam) and that of Nack *et al.* (2022) [32] in the upper course of River Nkam is not clear. The unsuitability of the physicochemical characteristics of River Nkam for survival of intermediate hosts (arthropods) and natural defenses against acanthocephalans the fish species in the River have been suggested. Crustaceans (copepods) were absent in fishes from the lower course of the River Nkam contrary to the findings of Nack *et al.* (2022) [32] who outlined the infection of the fish *Labeobarbus batesii* by copepods in the upper course of the River at about the same period of the year as the present study. Copepods may be accidental parasites for *Labeobarbus batesii*. Variation of the water physicochemical characteristics between the upper and lower courses of the River Nkam was also suggested for the absence of copepods in the lower course of the River.

The infections on the five fish species of the lower course of River Nkam could be due to the fact that the parasites share the same physicochemical environment. The fishes *Chrysichthys nigrodigitatus, Parachanna obscura and Clarias jaensis* harboured the highest number of parasitic groups (five parasite taxa over 5 five) suggest that they offer more nutritional resources to parasites and suitable biotope for their survival contrary to *Ctenopoma petherici* and *Oreochromis niloticus* which were infected only by four (80%) parasite groups. Multiple and various co-infections were observed in fishes revealed that pathogenic effects are not caused by single parasite species infection which agrees with Sitjà- Bobadilla (2008) [33] who reported that polyparasitism is due to the lack of competition between parasites. Though few single infections were observed in this study, parasites infecting a fish species have different metabolic and nutritional pathways since competition would result in elimination (migrations) of some parasites due to host changes. As per the Gause's principle, two or more parasites taxa in a given biotope will coexistence if have different exploitation patterns for the resource. Also, competitive exclusion arises when there is an overlap of the ecological niches and when the resource supply is greater than the demand. The parasites identified in this study are phylogenetically distant (Differents taxa) thus less competitive. The wide host range observed with monogeneans, nemotodes, trematodes and myxosporeans (infection of all the five fish species (100%)) was associated to the metabolic pathways of the parasites which enabled them to adapt to various biotopes.

The present work carried out in a natural environment showed a high overall prevalence (72.85%) similar to the findings of Nack *et al*. (2020) [11] who recorded 85% of monogenean (adult *Quadriacanthus* sp) infection of *Clarias camerunensis* captured in Lep Mōōga stream of the River Nyong watershed (Southern Cameroon). However, low parasite prevalence in lower courses

of natural environments have been reported by Amare *et al.* (2014) [7], Ali (2009) [18] and Habib *et al.* (2019) [28]. Low prevalence and transmissibility of parasites usually observed in the natural tributary milieu is due to the balance established during the evolution of the host / parasite system (Euzet and Pariselle, 1996 [34]). While fluctuation of the prevalence from low to high values in natural environments are linked to geographical differences of and fish species. Contrary to the upper course of River Nkam, a low overall prevalence (48%) was rather noted in the upper course (Nack *et al*., 2022 [32]). Pollution of the lower course of River Nkam with agricultural by products (organic waste) of local residents which provided favourable conditions for the proliferation of intermediate hosts and parasites as well as increase transmissibility of fish parasites played major roles in the high prevalence observed in the present study.

Activities that increase contact between fishes such as confinement of fish during breeding situation, harvesting of fish, high stocking density, muddy vase, low oxygenation and low depth of water usually cause increase in the prevalence of infections (Nack *et al.,* 2020 [21]; Fonkwa *et al*., 2020 [30]). Farming practices can modify the water physico-chemical characteristics resulting in favorable conditions for disease outbreaks with massive fish deaths and important economic losses due to stress and weaening of the immune system of fishes (Boungou *et al.,* 2013 [35]). The feeding habit of fish species and amount of ingested food can enhance the encounter between them and intermediate hosts (Ali, 2009) [18].

Overall, low to moderate relative abundances and mean intensities of monogeneans infection were were observed in the study. Low abundance of *Quadriacanthus* sp (monogenean) in *Clarias camerunensis* in the River Kellé (Nack *et al*., 2020 [11]) and low overall mean intensity of monogeneans of fishes in the upper course of the River Nkam by Nack *et al.* (2022 [32]) have been reported.

The present study showed that sex of fishes did not influence the parasitological indices. Previous studies of monogenean infections of *Parachanna obscura* in Lake Ossa (Littoral- Cameroon) (Nack *et al.* 2018 [10]), *Oreochromis niloticus, Cichlidogyrus thurstonae, C. halli* and *C. tilapiae* from Melen fish station in Yaounde-Cameroon (Tombi *et al*., 2004 [36]) did not observe any influence of sex on parasitological indices. No sex influence on the infestation rates *Dactylogyrus simplex* and *D. maillardi* on *Barbus martorelli* while in the Padda Dam (South Africa) (Tombi and Bilong, 2004 [37]) and monogeneans *Cichlidogyrus philander* on *Pseudocrenilabrus philander philander* (Le Roux *et al*., 2011 [38])

However, the prevalence and mean intensity were significantly higher in females than in males of *Oreochromis niloticus* and *Ctenopoma petherici*. Female fish especially gravid ones need more nutrients for the reproduction purposes and have comparatively reduced immuninty. This is contrary to [36] Tombi *et al*. (2004) had reported that prevalence and mean intensity of monogenean *Scutogyrus longicornis* is sex dependent with the parasites being significantly more in the male than female fishes.

Concerning the effect of the fish size classes on the indexes, two situations were reported. In the first situation, monogeneans were evenly distributed between almost all fish size classes. In the second situation, the abundance and mean intensity were size dependent. In fact, in *Parachanna obscura, Clarias jaensis* and *Ctenopoma petherici,* the abundance was remarkably affected by the size while in P*arachanna obscura,* the mean intensity was significantly higher in older/larger fish as compared to smaller/younger ones.

The effect of the fish size on the parasitological indices in the present study is similar to Nack *et al*. (2018) [10] and Boungou *et al.* (2008) [39] who reported that the size of *O. niloticus* in the dam of Loumbila (Ouagadougou) had no influence on the prevalence of monogenean gill parasites. The study also agrees with the finding of Tombi *et al.* (2004) [36] and Amare *et al.* (2014) [7] who observed that larger fishes were heavily parasitized than the smaller ones. Bigger and older fishes provide greater surfaces areas for the colonization and of accumulation of parasites (Cable *et al.,* 2002 [40], Bilong Bilong and Tombi, 2004 [41], Ibrahim, 2012 [42]). Also, some bigger fishes feed on the smaller ones as well as eat huge amount of food compared to smaller ones. Similar to the findings related to the size of the fish, the study showed significant increase parasitic prevalence (*C. petherici, P.obscura, Clarias jaensis*), relative abundance (*P. obscura, C. jaensis, C. petherici*) and mean intensity (*P. obscura)* with weights of the fish.

5 CONCLUSION

The parasitic fauna of fishes from the lower course of River Nkam was made up of five groups represented mostly by monogeneans as well as trematodes, myxosporeans, cestodes and nematodes. The overall prevalence of infection was high though the relative abundance and mean intensity of monogeneans infections ranged from low to average. Various influences of the parasitic prevalence, relative abundance and mean intensity due to fish species, sex, size and weight were observed in the study. The study provides relevant epidemiological data for the control of parasitic diseases of fishes in River Nkam and recommends quarantining and treatment of parasites before farming and harvesting purposes.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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