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Prevalence and associated risk factors of ectoparasite infections of cultured fish species in the West region of Cameroon

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Abstract
There is expansion of the fishery sector in Cameroon but there is dearth of information on the distribution, magnitude and risks of freshwater fish diseases in the country. This study was carried out to determine the prevalence and associated risk factors of ectoparasites on cultured fishes in West Cameroon. The external surfaces of 2254 randomly selected fishes (692 *Clarias gariepinus*, 969 *Oreochromis nilotichus*, 593 *Cyprinus carpio)* were examined using standard parasitological procedures. The results showed that 34.9% of sampled fishes were infected with ectoparasites including Crustaceans (12.0%), Monogeneans (15.8%) and Protozoans (15.8%). The prevalence was higher ($p<0.05$) in *Cyprinus carpio* compared to *Clarias gariepinus* and *Oreochromis niloticus* species. Female and large fishes were most infected ($p<0.05$) compared to male and small fishes. The study revealed mixed and high prevalence of ectoparasite infections of cultured fish species in West region of Cameroon and fish species, sex and size were the major risk factors.

Keywords: Cultured fish, crustaceans, monogeneans, protozoans, prevalence, risk factors, West region Cameroon

1. Introduction
Food scarcity and nutrient deficiency are major challenges of developing countries [1] including Cameroon where many communities are increasingly engaging in fish production due to continuous increase in human population, poverty alleviation and demand for animal protein [1-6]. However, increase in freshwater fish production implies intensifying production and many constraints with unknown impacts to productivity, trade and profitability of the fishery sector such as risks of parasite proliferation and compromised water quality [1, 2, 6-8]. Ectoparasites cause drop in performance and productivity in farms and damage to the livelihood of farmers, loss of job, reduced incomes and food insecurity [9]. New diseases may emerge due to intensification of production, production in new locations, introduction of new species and culture methods.
Parasite infections of fishes affect their physiology causing depression of the immune system as well as injury and damage to the tissues and organs they infect and secretion of proteolysis enzymes [2, 8]. Parasites compete with fish for food, deprive them of essential nutrients, inhibit their growth; increase their susceptibility to predation, reduce their growth during and after outbreak of the disease and cause economic losses via their reduced trade value, treatment expenses and death [2, 7, 8]. Ectoparasite prevalence of cultured fish species ranging from 33.3 – 84.8% in Nigeria [10, 11], 4.7 – 20.9% in Tanzania (Mdegela *et al.* 2011) and 3.3 – 31% in Kenya [10] have been recorded.
In Cameroon, continuous increase in human population and increase demand for food of animal origin has led to intensification of livestock and fish production. Though fish farming is increasing in many communities in Cameroon, the total domestic fish production of about 180,000-tonnes per annum is far less than the estimated demand of about 400,000 tonnes annual [12] and the country can not meet the FAO's minimum recommended fish consumption rate of 12.5 kg per head yearly to satisfy basic protein needs [6, 12]. Many factors including lack of measures to control parasitic diseases and transmission of parasites could be contributing

to the low fish production levels. The expansion of the fishery sector with potentials for increased production is essential but there is dearth of information on the distribution, magnitude and risks of freshwater fish diseases in the country. Therefore, understanding the epidemiology and risks factors of ectoparasites of cultured fish species will provide key elements for their control with positive effects on productivity and level of awareness among fish farmers. In this context, this study was carried out to determine the prevalence and associated risk factors of ectoparasites on cultured fish species in West region of Cameroon.

2. Materials and Methods

2.1 Description of study area

The study was carried out in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West region of Cameroon (9°50' – 10°20' E and 5°10' – 5°40' N) (Figure 1). The West Region has a typical sudano-guinean climate characterised by a short dry season (mid-November – mid-March) with a temperature range of 20 – 27 ºC, long rainy season (mid-March – Mid-November) and temperature range of 16 – 23 ºC, average annual rainfall of 1600 mm and relative humidity ranging from 49 – 97.9% [13].

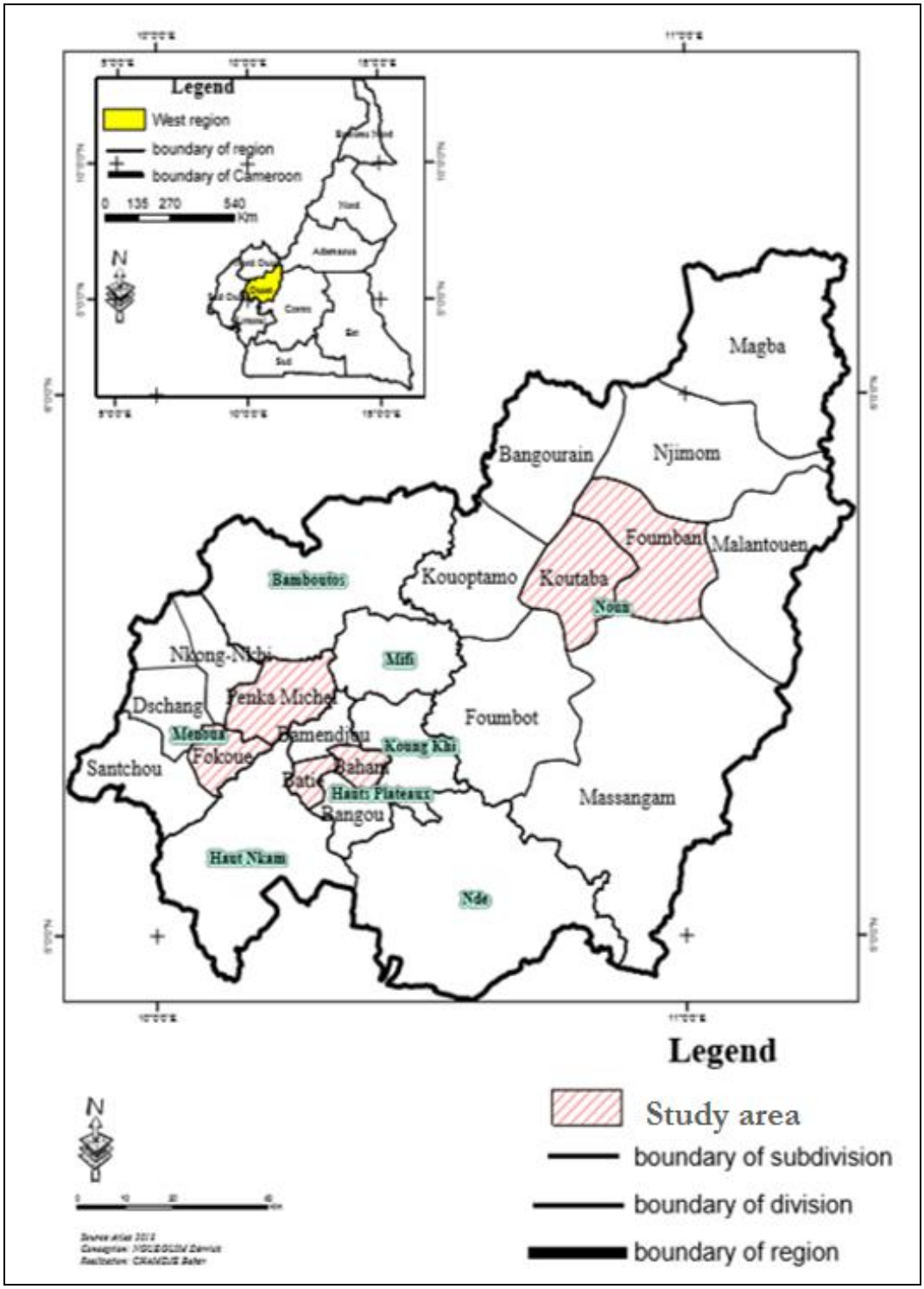

Fig 1: Map of Cameroon showing the West region, the administrative divisions in the region and administrative sub-divisions with study sites within Menoua, Noun and Hauts-plateaux administrative divisions. (Source: The Dschang Urban council in collaboration with the Cartography Unit of the University of Dschang, Cameroon produced the maps including study areas shaded pink in Menoua, Noun and Hauts-plateaux administrative divisions)

2.2 Selection of fish farms and samples for the study

A cross-sectional study was carried out during December 2018 to December 2019 of fish farms in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West region of Cameroon. The estimation of the number of farms and individual fishes for the study was done as previously described [14] and selected by random-number generation method, without replacing numbers, of fish farmers and locations of fish farms from records at the Divisional Delegations of Livestock, Fishery and Animal Industries (DDEPIA). Selection of individual fish from each chosen farm was based on a calculated sampling fraction of five (every fifth fish was sampled) for use at each visit during harvesting. Briefly, the first fish was selected by picking a fish by random generation method from the first five fish being transferred to the temporal storage chain for transportation to the market and thence every fifth fish was chosen as sample.

Overall, nine fish farms (03 per administrative division) and 2254 cultured fish species from fish farms in Menoua (522), Hauts-plateaux (775) and Noun (957) divisions were selected for the study. Following proper labelling, preliminary examination for identification characteristics and presence of ectoparasites [2, 15], the fish samples were transported to the Ichthyology and Applied Hydrobiology Laboratory of the University of Dschang for dissection and further analyses within 12 hours after capture. The fish species determined with the aid of previously described keys [16] were composed of *Clarias gariepinus* (692), *Cyprinus Carpio* (593) and *Oreochromis niloticus* (969).

2.3 Morphometric measurements and determination of the sex of fish

The size (standard and total lengths (cm)) and weight (gm) of each fish was measured. The sizes (x) were classified according to Shehata *et al.* [17] as follows: small sizes of (25cm ≥ x < 40 cm) for *C. gariepinus*, (12 cm ≥ x < 22 cm) for *C. Carpio* and (14 cm ≥ x ≤ 21 cm) for *O. niloticus* and large sized group; being 40 cm ≥ x ≤ 55 cm for *C. gariepinus*, 22 cm ≥ x ≤33 cm for *C. Carpio* and from 22 cm ≥ x ≤30 cm for *O. niloticus*. The weights (X) were classified based on Biu *et al.*, [18] as follows X<50gm, 50gm<X≤100gm, 100gm<X≤150gm, 150gm<X≤200gm and X>250gm.

The sex of the fish specimens were determined by pressing the abdomen of adult fishes to cause the release of whitish milk for males and eggs for females, otherwise the fishes were dissected and the gonads examined using previously described procedures [19, 20].

2.5 Detection of ectoparasites on fish

The fish samples were examined for ectoparasites using hand lens [8, 21-23]. Systematic scraping from the skin (head to tail), fins and gills of the sampled fishes were mixed with 3ml of 0.9% saline, smeared on clean grease-free glass slides and examined under the light microscope. Each sample was examined independently as described by Ekanem *et al.* [21]. The identification of the ectoparasites was based on distinctive morphological features using reference keys for taxa of fish parasites [2, 15, 21, 24]. An infected fish sample was coded as 1 and uninfected as 0.

2.6 Data analysis

The obtained data was entered into Microsoft office Excel 2007 for descriptive statistics and transferred to the Statistical Package for the Social Sciences (version 22, SPSS Inc., USA) for further statistical analysis. The ectoparasite prevalence rate calculated as the proportion of infected fish of the total number of fish examined and expressed as a percentage [14, 25]. The chi-square test was used to test significant levels within factors on prevalence rates and odds-ratios were determined for associated risk factors along 95% confidence intervals and statistical significance set at P<0.05.

3. Results

3.1 Prevalence and associated risk factors of ectoparasite on cultured fishes

The study showed mix fish species farming of *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* infected by multiple ectoparasites (single and co-infections) in West region of Cameroon. Overall, 786 (34.87%; 95%CI (32.93 – 36.86) of the fishes sampled were infected with Monogeneans (356; 15.79% [14.34 – 17.35]), Protozoans (356; 15.79% [14.34 – 17.35]) and Crustaceans *(271; 12.02% [10.74 – 13.43])* at individual level (Table 1). The Monogeneans included *Gyrodactylus sp.* (285; 12.64% (11.33 – 14.08) and *Dactylogyrus sp.* (117; 5.19% (4.35 – 6.18%). The Protozoans were *Myxozoa sp* (232; 10.29% (9.10 – 11.62), *Trichodina sp* (159; 7.05% (6.06 – 8.18) and *Chidonella sp.* (12; 0.53% (0.30 – 0.93). The Crustaceans were *Argulus foliaceus* (150; 6.65% (5.69 – 7.75) and *Copepoda spp*. (150; 6.65% (5.69 – 7.75) [*Lernea cyprinacea (95; 4.21%* (3.46 – 5.12*)* and *Ergasilus sielboldi* (55; 2.44% (1.88 – 3.16)].

Overall, *Cyprinus carpio* was the most infected species though fish species (P=0.40, X^2=1.85) and husbandry (pond) system (P=0.07, X^2=3.21) were not associated with increase of ectoparasite infection of the cultured fishes. The sex (P=0.02, X^2=5.78), size (P=0.001, X^2=10.59), weight of the fish species (P<0. 0001, X^2=32.24), locality of farm (P=0.01, X^2=10.51) and season (P<0.00001, X^2=81.72) significantly influenced the ectoparasites prevalence of the cultured fishes. However, fish species played major roles for ectoparasite infections with Monogeneans (P=0.030, X^2=7.010) and Crustaceans (P=0.02, X^2=8.09) and not with Protozoans (P=1.68, X^2=3.57). The prevalence of Monogeneans and Crustaceans was higher (p<0.05) on *Cyprinus carpio* than the other fish species (Table 1). The study recorded higher (p<0.05) prevalence rates among large and female fishes, fishes kept in unintegrated ponds, fishes in farms located in the Hauts-Plateaux and Noun Divisions and fishes raised during the dry season. However, light weight fishes (≤ 100 gm, 66.08% prevalence), showed higher (p<0.00001, X^2=26.10) rates compared to heavier weight fishes (> 100 gm, 58.16% prevalence).

The study revealed that all farms (100%) were infected irrespective of their location, season, farmer's level of educational, religion and farm practice in West Region of Cameroon.

3.2 Effect of farmer's qualities and farm practice on ectoparasites infection of cultured fishes

The prevalence of ectoparasites of cultured fishes at individual level was significantly (p<0.05) influenced by the frequency of their feeding (twice daily, after 2 days), level of education (never, primary) and religion (Muslim, Animist) of the farmers. Fishes that were fed twice daily and after every two days, farms owned or managed by Muslim and Animist and respondents with low level of education (never been to school and Primary school level) showed higher (p<0.05) ectoparasites prevalence rates of fishes (Table 2).

3.3 Type of combinations of ectoparasite infections of cultured fish species

Prevalence of various ectoparasite combinations were influenced by species, sex and size of the sampled fishes. The prevalence of single ectoparasite groups was significantly higher ($p<0.05$) compared to the multiple combinations and infections with double ectoparasite groups were higher ($p<0.05$) than infections with triple ectoparasite groups. Overall, there were ectoparasite infections of sampled fishes with the single group / type (27.20%) (Monogenean (8.74% (7.64 – 9.98%)); Protozoan (11.36% (10.12 – 12.74%)) and Crustacean (7.10% (6.11 – 8.23%)) groups /types of ectoparasite) as well as simultaneous multiple infections (7.68% (6.65 – 8.85%)) (double (6.57% (5.62 – 7.67%)) and triple (1.11% (0.75 – 1.63%)) ectoparasites group combinations) in the present study (Table 3). Also, 414 (18.37% (16.83 – 20.02%)) of all sampled fish species were simultaneously co-infected by parasites of the same ectoparasite group including 46 (2.04% (1.53 – 2.71%)) for Monogenean; 47 (2.09% (1.58 – 2.77%)) for Protozoan and 124 (5.50% (4.63 – 6.52%)) for Crustacean groups.

3.4 Location of ectoparasites on cultured fish species

Overall, the detected ectoparasites were most frequently on the gills (26.8%) and fins (24.8%) followed by the operculum (5.9%), skin (1.2%) around the eyes (0.4%) of the sampled fish species. The trend of proportionate distribution of location sites of ectoparasites was similar in the different fishes; namely; *Cyprinus carpio* (2.7% Skin, 30.7% Gill, 18.7% Fins, 6.7% Operculum, 0.5% Eyes), *Clarias gariepinus* (0.7% Skin, 19.9% Gill, 34.5% Fins, 1.9% Operculum, 1.0% Eyes) and *Oreochromis niloticus* (0.5% Skin, 24.8% Gill, 8.7% Fins, 4.0% Operculum, 0% Eyes). In descending order of preference of the predominant ectoparasite location sites on the fishes: the Monogeneans infected the gills (11.4%), fins (6.9%), operculum (4.0%) and skin (0.2%); the Protozoans infected the fins (11.4%), gills (9.2%), skin (0.7%) and around the eye (0.4%) while the Crustaceans infected the fins (6.4%), gills (6.1%), operculum (1.9%) and skin (0.3%).

Table 1: Prevalence and associated factors of ectoparasites of cultured fish species at individual level in West Region of Cameroon

Factors	Variable	Type of ectoparasite						Total	
		Monogeneans		Protozoans		Crustaceans			
		Prevalence % (95% CI)	Odds ratio (95%CI) p value [X^2]	Prevalence % (95% CI)	Odds ratio (95%CI) p value [X^2]	Prevalence % (95% CI)	Odds ratio (95%CI) p value [X^2]	Prevalence % (95% CI)	Odds ratio (95%CI) p value [X^2]
Overall	All sampled fish (N=2254)	15.79 (14.35-17.36)a		15.79 (14.34-17.36)a		12.02 (10.74-13.43)b		34.87 (32.93-36.86)	
Fish specie	*Oreochromis niloticus* (N=969)	13.73 (11.70-16.03)b	-	15.07 (12.95-17.45)a	1.03 (0.78 – 1.35) 0.86 [0.03]	12.38 (10.46-14.61)ab	1.36 (0.99 – 1.88) 0.056 [3.65]	34.37 (31.44-37.41)a	1.03 (0.84 – 1.27) 0.76 [0.09]
	Cyprinus carpio (N=593)	18.72 (15.78-22.06)a	1.45 (1.10– 1.91) 0.009 [6.96]	18.21 (15.31-21.52)a	1.23 (0.96 – 1.73) 0.093 [2.82]	14.50 (11.90-17.57)a	1.64 (1.16 – 2.31) 0.005 [8.04]	37.10 (33.31-41.06)a	1.16 (0.92 – 1.46) 0.199 [1.65]
	Clarias gariepinus (N=692)	16.18 (13.63-19.11)ab	1.21 (0.92 – 1.59) 0.164 [1.94]	14.74 (12.29-17.58)a	-	9.39 (7.44-11.80)b	-	33.67 (30.25-37.27)a	-
Sex of fish	Male (N=998)	15.53 (13.42-17.91)a	-	13.93 (11.92-16.21)b	-	10.42 (8.67-12.47)b	-	32.16 (29.34-35.13)b	-
	Female (N=1256)	16.00 (14.08-18.13)a	1.04 (0.82 – 1.30) 0.764 [0.09]	17.28 (15.29-19.47)a	1.29 (1.02 – 1.63) 0.030 [4.69]	13.30 (11.53-15.29)a	1.32 (1.01 – 1.71) 0.037 [4.35]	37.02 (34.40-39.73)a	1.24 (1.04 – 1.48) 0.016 [5.78]
Size of fish*	Small (n=1794)	14.66(13.10-16.37)b	-	17.56 (15.87-19.39)a	2.18 (1.54 – 2.69) < 0.0001 [20.58]	12.21 (10.77-13.80)a	1.09 (0.79 – 1.50) 0.597 [0.28]	28.70 (24.75-32.99)a	-
	Large (n=460)	20.22 (16.80-24.13)a	1.48 (1.13 – 1.92) 0.004 [8.50]	8.91 (6.64-11.87)b	-	11.30 (8.73-14.52)a	-	36.45 (34.26-38.71)b	1.43 (1.15 – 1.77) 0.001 [10.59]
Mass (gm)	X<50gm (N=855)	14.26 (12.08-16.77)bc	1.34 (0.93 – 1.95) 0.124 [2.36]	18.95 (16.46-21.71)a	3.66 (1.83 – 7.34) < 0.0001 [15.15]	13.33 (11.22-15.78)b	1.79 (1.18 – 2.74) 0.006 [7.55]	37.54 (34.36-40.84)ab	1.91 (1.45 – 2.50) < 0.0001 [21.88]
	50gm<X≤100gm (N=607)	17.96 (15.11-21.21)b	1.76 (1.20 – 2.58) < 0.003 [8.6]	19.28 (16.33-22.60)a	3.74 (1.85 – 7.56) < 0.0001 [15.28]	11.37 (9.08-14.14)c	1.50 (0.95 – 2.34) 0.077 [3.12]	40.20 (36.37-44.15)a	2.13 (1.60 – 2.84) < 0.0001 [27.52]
	100gm<X≤150gm (380)	11.05 (8.28-14.60)c	-	10.00 (7.37-13.43)b	1.74 (0.82 – 3.69) 0.144 [2.13]	7.89 (5.59-11.05)c	-	23.95 (19.93-28.49)c	-
	150gm<X≤200gm (262)	14.50 (10.75-19.28)bc	1.37 (0.85 – 2.18) 0.194 [1.69]	11.45 (8.14-15.86)b	2.03 (0.93 – 4.39) 0.069 [3.31]	9.16 (6.23-13.27)c	1.18 (0.67 – 2.06) 0.572 [0.32]	31.68 (26.35-37.54)b	1.47 (1.04 – 2.09) 0.030 [4.69]
	X>250gm (N=150)	30.00 (23.24-37.76)ab	3.45 (2.15 – 5.41) < 0.0001 [28.14]	6.00 (3.19-11.01)b	-	22.67 (16.70-30.00)a	3.42 (2.00 – 5.83) < 0.0001[22.1]	31.33 (24.46-39.14)bc	1.45 (0.95 – 2.20) 0.081 [3.05]
Pond system#	Integrated (N=270)	11.48 (8.21-15.84)b	-	16.30 (12.37-21.17)a	1.04 (0.74 – 1.47) 0.806 [0.06]	7.78 (5.14-11.60)b	-	30.00 (24.85-35.72)a	-
	Unintegrated (N=1984)	16.38 (14.82-18.07)a	1.51 (1.02 – 2.24) 0.038 [4.29]	15.73 (14.19-17.39)a	-	12.60 (11.21-14.13)a	1.71 (1.07 – 2.72) 0.022 [5.23]	35.53 (33.46-37.67)a	1.29 (0.98 – 1.70) 0.073 [3.21]
Locality (Division) of farm	Menoua (N =522)	15.52 (12.66-18.87)a	1.02 (0.75 – 1.39) 0.888 [0.02]	15.71 (12.84-19.08)a	1.05 (0.77 – 1.42) 0.764 [0.09]	5.56 (3.90-7.86)b	-	29.12 (25.39-33.16)b	-
	Hauts-plateaux (N =775)	15.23 (12.87-17.93)a	-	15.10 (12.75-17.79)a	-	14.19 (11.91-16.83)a	2.81 (1.84 – 4.30) < 0.0001 [24.32]	35.61 (32.32-39.05)a	1.34 (1.06 – 1.71) 0.015 [5.95]
	Noun (N =957)	16.41	1.09 (0.84 – 1.42)	16.41	1.10 (0.85 – 1.43)	13.79	2.72 (1.79 – 4.13)	37.41	1.45 (1.16 – 1.83)

		(14.19-18.89)a	0.502 [0.45]	(14.19-18.89)a	0.458 [0.55]	(11.75-16.12)a	< 0.0001 [23.63]	(34.40-40.52)a	0.001 [10.27]
Season of the year	Dry (N=1278)	17.84 (15.84-20.03)a	1.44 (1.14 – 1.82) 0.002 [9.29]	18.31 (16.29-20.52)a	1.57 (1.24 – 1.99) 0.0002 [14.04]	19.25 (17.18-21.50)a	9.07 (5.95 – 13.81) < 0.0001 [145.69]	42.80 (40.11-45.53)a	2.31 (1.92 – 2.77) < 0.0001 [81.72]
	Wet season (N=976)	13.11 (11.14-15.38)b	-	12.50 (10.57-14.72)b	-	2.56 (1.74-3.75)b	-	24.49 (21.89-27.28)b	-

*: The sizes (x) were classified according to Shehata *et al*. (2018) as follows: small sizes of (25cm ≥ x < 40 cm) for *C. gariepinus*, (12 cm ≥ x < 22 cm) for *C. Carpio* and (14 cm ≥ x ≤ 21 cm) for *O. niloticus*, and large sized group; being 40 cm ≥ x ≤ 55 cm for *C. gariepinus*, 22 cm ≥ x ≤33 cm for *C. Carpio* and from 22 cm ≥ x ≤30 cm for *O. niloticus.*

#: integrated system = intensive; Unintegrated system = extensive, traditional

a, b, c: Same letters in column are not significantly different

Table 2: Prevalence of ectoparasites of cultured fish species at individual level according to farmer's level of educational, religion and farm practice in West Region of Cameroon

Factors	Variable	Number of sampled fish	Number of infected fish	Prevalence% (95%CI)	P (X^2)	Odds ratio (95%CI)	P (X^2)
All farms	All farms	**2254**	**786**	34.87 (32.93-36.86)			
Feeding frequency	Everyday : Once daily	746	222	29.76 (26.59-33.14)a	0.004* (8.25)	-	
	Everyday : Twice daily	988	359	36.34 (33.40-39.38)b		1.34 [1.10 – 1.65]	0.004 (8.25)
	Everyday : total	1734	581	33.51 (31.32-35.76)c	0.013* (6.17)	-	
	After every 2 days	520	205	39.42 (35.32-43.69)d		1.29 [1.06 – 1.58]	0.013 (6.17)
Experience of farmer in fish farming (x years)	≤ 10	224	70	31.25 (25.54-37.59)a	0.462 (1.54)	-	
	10<x≤ 20	688	246	35.76 (32.27-39.41)a		1.22 [0.89 – 1.69]	0.218 (1.52)
	>20	1342	470	35.02 (32.52-37.61)a		1.19 [0.88 – 1.61]	0.271 (1.21)
Duration of culture period or Breeding cycle (months)	≤ 6	251	93	37.05 (31.31-43.18)a	0.442 (0.59)	1.11 [0.85 – 1.46]	0.442 (0.59)
	>6	2003	693	34.60 (32.55-36.71)a		-	
Compliance rate of biosecurity (X)	Low (X≤ 25%)	1703	580	34.06 (31.85-36.34)a	0.154 (2.03)	-	
	Moderate [25%< X <75%]	551	206	37.39 (33.45-41.50)a		1.16 [0.95 – 1.41]	0.154 (2.03)
Level of education of farmer	Never been to school	*218*	*79*	*36.24 (30.15-42.81)ab*	0.052* (5.93)	1.19 [0.88 – 1.61]	0.265 (1.24)
	Primary	957	358	37.41 (34.40-40.52)a		1.25 [1.04 – 1.50]	0.017 (5.74)
	Secondary	1079	349	32.34 (29.62-35.19)b		-	
Religion of farmer	Christian	*522*	*152*	*29.12 (25.39-33.16)b*	0.005* (10.51)	-	
	Muslim	957	358	37.41 (34.40-40.52)a		1.45 [1.16 – 1.83]	0.001 (10.27)
	Animist	775	276	35.61 (32.32-39.05)a		1.35 [1.06 – 1.71]	0.015 (5.95)
Pond water Source	River	1703	580	34.06 (31.84-36.34)a	0.154 (2.03)	-	
	Bore holes	551	206	37.39 (33.45-41.50)a		1.16 [0.95 – 1.41]	0.154 (2.03)

* = Significant p-value.

a, b, c, d : Same letters in column for the same category are not significantly different (p>0.05)

Table 3: Prevalence and risk factors of combinations of ectoparasite infections of cultured fish species in West region Cameroon

Factors	Variable	Single infections only % (95%CI)				Double infections only % (95%CI)				Triple infections % (95%CI)
		Monogeneans	Protozoans	Crustaceans	Total of single infections	Monogeneans + Protozoans	Monogeneans + Crustaceans	Protozoans + Crustaceans	Total of double infections	Monogeneans + Protozoans + Crustaceans
Fish species	*Oreochromis niloticus* (n=969)	8.05 (6.50-9.93)a	11.04 (9.22-13.17)a	9.29 (7.62-11.28)a	28.38 (25.63-31.30)a	3.41 (2.44-4.75)a	1.86 (1.18-2.92)b		5.26 (4.03-6.85)a	1.14 (0.64-2.03)a
	Cyprinus Carpio (n=593)	6.07 (4.42-8.29)a	11.97 (9.60-14.83)a	3.37 (2.19-5.15)b	21.42 (18.31-24.90)b	4.05 (2.74-5.95)a	8.94 (6.90-11.51)a	2.02 (1.16-3.50)a	15.01 (12.36-18.11)b	
	C. gariepinus (n=692	11.99 (9.78-14.62)b	11.27 (9.12-13.84)a	7.23 (5.53-9.40)a	30.49 (27.18-34.02)a	1.01 (0.49-2.07)b		0.14 (0.02-0.81)b	1.16 (0.59-2.27)c	2.02 (1.21-3.36)a
Sex of fish	Male (n=998)	10.12 (8.40-12.15)a	8.72 (7.12-10.63)a	6.61 (5.23-8.32)a	25.45 (22.85-28.24)a	2.81 (1.95-4.03)a	1.40 (0.84-2.34)a	1.10 (0.61-1.96)a	5.31 (4.08 -6.88)a	1.20 (0.69-2.09)a
	Female (n=1256)	7.64 (6.30-9.24)b	13.46 (11.68-15.46)b	7.48 (6.15-9.07)a	28.58 (26.15-31.14)a	2.87 (2.08-3.95)a	4.54 (3.52-5.84)b	0.16 (0.04-0.58)b	7.56 (6.22-9.15)b	1.04 (0.61-1.77)a
Size of fish (cm)	Small (n=1794)	8.81 (7.58-10.21)a	12.37 (10.93-13.97)a	8.64 (7.43-10.03)a	29.82 (27.75-31.98)a	3.18 (2.46-4.10)a	1.34 (0.90-1.99)a	0.72 (0.42-1.23)	5.24 (4.30-6.37)a	1.39 (0.94-2.04)
	Large (n=460)	8.48 (6.27-11.38)a	7.39 (5.34 -10.15)b	1.09 (0.47-2.52)b	16.96 (13.81-20.66)b	1.52 (0.74-3.11)a	10.22 (7.77-13.33)b		11.74 (9.11-15.00)b	
Weight of fish (gm)	X<50gm (N=855)	6.32 (4.88-8.15)a	12.98 (10.89-15.40)a	8.42 (6.74-10.47)a	27.72 (24.84-30.81)a	2.67 (1.80-4.00)a	6.08 (4.67-7.89)a	0.58 (0.25-1.35)a	9.36 (7.59-11.50)a	1.29 (0.72-2.29)a
	50gm<X≤100gm (N=607)	10.87 (8.64-13.60)b	11.20 (8.93-13.96)a	13.01 (10.56-15.92)b	35.09 (31.40-38.97)b	2.64 (1.63-4.24)a	2.64 (1.63-4.24)b	1.32 (0.67-2.58)a	6.59 (4.88-8.85)ab	2.31 (1.38-3.84)a
	100gm<X≤150gm (380)	11.58 (8.74-15.19)b	10.79 (8.05-14.31)a	2.11 (1.07-4.10)c	24.47 (20.42-29.03)ac	4.21 (2.61-6.73)a	0.79 (0.27-1.00)c		5.00 (3.22-7.68)b	
	150gm<X≤200gm (262)	9.54 (6.55-13.70)ab	8.78 (5.92-12.83)a	0.38 (0.07-2.13)c	18.70 (14.44-23.86)cd	3.44 (1.82-6.40)a			3.44 (1.82-6.40)b	
	X>250gm (N=150)	5.33 (2.72-10.17)a	8.67 (5.14-14.27)a		14.00 (9.34-20.46)d					
Total (N=2254)		8.74 (7.64-9.98)A	11.36 (10.12-12.74)B	7.10 (6.11-8.23)C	27.20 (25.40-29.07)*	2.84 (2.23-3.61)A	3.15 (2.50-3.95)A	0.58 (0.34-0.99)B	6.57 (5.62-7.67)*	1.11 (0.75-1.66)*

a, b, c d,: Same letters for a category (Factor) in a column are not significantly different (p>0.05)
A, B, C, D, E: Same letters for a category (single, double and triple infections) in a line are not significantly different (p>0.05)
*: Total values are significantly different (p<0.05)

4. Discussion

The study revealed mix fish species farming of *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* with high prevalence of multiple ectoparasites (single and co-infections) in the West region of Cameroon. The overall prevalence of 34.87% at individual level and 100% at farm level were observed. Eight species of fish ectoparasites were identified including Monogeneans (*Gyrodactylus sp.* and *Dactylogyrus sp.*), Protozoans (*Myxozoa sp.*, *Trichodina sp.* and *Chidonella sp.*) and Crustaceans (*Argulus foliaceus* and *Copepoda spp.*, [*Lernea cyprinacea* and *Ergasilus sielboldi*]) on the gill, operculum, skin and fins of the sampled fishes. Varying prevalence rates of the ectoparasites recorded in the present study have been reported on gill, operculum, skin and fins of freshwater fishes in Africa and other parts of the world [2, 7, 10, 21, 26-28]. The gills of many fishes were infested by different parasites due to the sieving ability of the gill which trapped the organisms [2, 10].

The high ectoparasites prevalence and co-infection rates recorded in the present study was associated to many factors including high stocking density of ponds, poor hygiene conditions and biosecurity scores of farms and susceptibility of the fish hosts. Overall, the prevalence of combinations of ectoparasite groups were influenced by species, sex and size of the sampled fishes and was highest for single infections only followed by the double and triple combinations of ectoparasite groups. High stocking density and overcrowding of the ponds lead to closer contacts and easy transmission of parasites between fishes [2]. Poor or lack of compliance of biosecurity measures, non-respect of fish farm practice and management related factors such as pollution of the ponds and poor physico-chemical quality of fishpond-water favoured survival and proliferation of the ectoparasite groups. Total ectoparasite infection rates of over 48.82% for *Clarias gariepinus*, *Oreochromis nilotichus* and *Heterobranchus longifilis* in Nigeria [29, 30] and 70% for *Clarias gariepinus* in Egypt [27] have been recorded. High incidence approaching 100% are common in most fish species associated with monogeneans and crowding fish into culture systems often promotes infestation [2]. However, inhibitive quality of physical (depth, currents, temperatures) and chemical (oxygen, salinities) factors of the environment have caused low infection rates and decline in diversity of monogenean species [1, 2, 29-31]. Reduced mobility of the fish facilitates colonisation of ectoparasitic protozoans and heavy infections are mainly found in young and small fishes when overcrowded and confined to restricted habitats and under stress conditions including inadequate feeding, intermittent high and low ambient temperatures, crowding in residual pools in rivers drying-out during the dry season [2, 7, 8]. Crustacean parasites vary in their level of host specificity and moderate to high infection rates have been recorded in African lakes and rivers [2, 27, 29, 30]. The fastidious, nutritive and environmental requirements of the free-living stages seem to limit distribution of crustaceans when their hosts are translocated which explains the fact that very few crustacean species ever become established in pond systems [1, 2, 31]. The low (5.06%) *Dactylogyrus sp.* infection rates of fishes in this study is similar to Tesfaye *et al.* [32] who recorded *Dactylogyrus spp.* infection rates (4%) in *Labeo spp.* and *Barbus spp.* in Ethopia. However, higher *Dactylogyrus spp.* rates were reported in Kenya (22.5%), Uganda (55%) and Ethiopia (16%) [33]. The dynamic nature of parasitism, geographical locations of farms offering suitable ecological niches for the parasites and susceptibility of hosts could be responsible for variation in prevalence rates of fish ectoparasites.

Though pond systems and source of water did not influence ectoparasite infections of cultured fish in this study, the prevalence was higher in unintegrated earthen ponds and ponds supplied by water from bore-holes than integrated concreted floored ponds and ponds supplied by water from rivers. The finding is contrary to higher parasite infestation rates observed for fishes reared in earthen (20.9%) and concrete ponds (4.7%) in Tanzania [34] and earthen (31%) and concrete ponds (3.3%) in Kenya [35]. The mud in earthen ponds provides a favourable environment for survival and establishment parasites. The fishes in this study were supplied farm-made foods, agro-industrial by-products, livestock waste (pig slurry, hen droppings and cattle manure). Feeding twice daily and once every two days resulted in excess remains of feed not immediately consumed by the fishes in the ponds (adding to the organic substance or biological of the water) which provide favourable conditions for proliferation, multiplication and growth of microorganisms including parasites. The accumulation and decomposition of excess livestock waste as organic fertilizer and food for the cultured of fishes in the ponds provided suitable conditions for parasites to flourish and thrive [36]. High organic load of the pond water and high environmental temperature and stressful conditions [2, 7, 8] are suitable conditions for parasitic disease outbreaks.

In the study, most farmers sourced pond water from rivers which agrees with Mdegela *et al.* [34] in Tanzania, Ngwili *et al.* [37], Mavuti *et al* [38] and Maina *et al.* [35] in Kenya who reported that rivers were the main source for fishpond water which introduced potentially pathogenic microorganisms to fishes. The finding is contrary to earlier reports of springs and boreholes as the main water sources in Kenya [39] and in Nigeria [40]. The significant effect of sex, size and heavier (>100gm) on infection rates in the present study was associated to large size and female fishes having stayed and been exposed to ectoparasites longer in the ponds than male, small size and lighter weight (<100gm) fishes. These findings are in agreement with Ogonna *et al*., [30] who recorded higher infections rates in females (49.35%), larger fishes (65%) and >120g weight (100%) than males (48.00%), smaller (17%) and <120 g weight (41.6 – 76.92%) ones. The higher prevalence rates recorded in the present study for female fishes could be due to differential feeding behaviours, quantity and quality of food and difference in level of resistance to infection. The higher prevalence rates recorded with large size fishes agrees with earlier reports [11, 22, 23, 26] that bigger and longer fishes have more parasites compared to small fishes. The bigger fishes were more exposed to the ectoparasites as well as they engaged and fed more on diverse food sources due to their size than small size fishes. Ecological characteristics of the location of the farms explained the difference prevalence rates observed. The finding of the study seem to suggest the relation between ectoparasite infections of cultured fishes in the study farms is positive for size and negative for the mass / weight of the fishes. The juvenile fish are seem to be more susceptible to parasitic infection and prevalence rate reduced with age of fishes.

Poor management and biosecurity practices explained the higher prevalence rates recorded in unintegrated pond systems and dry season fishery husbandry. In addition, the drop in

volumes and poor quality of fishpond waters are common during the dry season favouring survival and growth of microbes including parasites. Heavy infection of confined fishes in habitats such as small dams, fish ponds and regressing pools in riverbeds at the dry seasons have be reported [2]. In the present study *Cyprinus carpio* was the most infected species compared to *O. niloticus* and *C. gariepinus*. The feeding biology of fishes depends on food availability (animal and plant origin), season, habitat differences and size of the fish [41-44]. The feeding habits of *O. niloticus* shift from omnivorous to herbivorous with increase in size or from juvenile to adults [43, 44] and from omnivorous to carnivorous with increase in size or from juvenile to adults for *Clarias gariepinus* [41, 43]. Generally, *Cyprinus carpio* are omnivorous in their feeding habits, though food of animal origin dominate the diets of juveniles / young and food of plant origin the diets of the adults [42]. Normally, *C. gariepinus* are bottom feeders, but their feeding habits are adaptable and they filter feed in groups at the water surface. Their feeding modes (individual foraging, individual shovelling, surface feeding and formation feeding) depend on food available [42, 43, 45]. The carnivorous behaviours and feeding modes could be responsible for the lower prevalence (33.67%) and predominance of predilection sites of ectoparasites particularly the fins for *C. gariepinus* (19.9% Gill, 34.5% Fins) compared to higher prevalence (over 34.40%) and predilections sites for *Cyprinus carpio* (30.7% Gill, 18.7% Fins) and *Oreochromis niloticus* (24.8% Gill, 8.7% Fins).

The prevalence of ectoparasites of cultured fishes at individual level was higher in farms managed by famers with low level of education (never been to school and Primary school level) compared to farms owned by farmers with higher educational level (secondary school level). Husbandry (pond) systems were not associated with increase of ectoparasite infection of the cultured fishes. However, the low to moderate compliance rate of biosecurity (poor biosecurity scores) recorded even with long experiences (>10 years) of the respondents in fish farming in the study suggest negligence of farm hygiene conditions and standard fish farming practices as well as poor understanding of biosecurity measures of farmers. However, the respondents were of mixed religions and all of them reported having at least primary school educational level. These findings suggest no socio-cultural and religious taboos in fish husbandries and that proper training in the domain would have positive influences on hygiene practices, biosecurity compliance levels and farm practices with consequent reduction on the prevalence of parasites and improvement in the productivity of the fish farms in the region. The positive influences of good education, training and experience on fish farming techniques and the gross economic potential of the fish sector has been described [39]. Good educational level and fish farming training in collaboration with academic and fishery industry partners can improve the poor biosecurity scores observed in this study.

5. Conclusion

The study revealed mix fish species farming of *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* with high prevalence of ectoparasites co-infection in the West region of Cameroon. The eight ectoparasite species detected include Monogeneans (*Gyrodactylus sp.* and *Dactylogyrus sp.*), Protozoans (*Myxozoa sp., Trichodina sp.* and *Chidonella sp.*) and Crustaceans (*Argulus foliaceus* and *Copepoda spp.*, [*Lernea cyprinacea* and *Ergasilus sielboldi*]). The overall prevalence was 34.87% at individual level and 100% at farm level. The sex, size, weight of the fish species; farm practice such as feeding frequency and educational level of farmers as well as locality and season were the major risk factors of ectoparasites of cultured fishes in the study area. However, the different rates and combinations of fish ectoparasites recorded in this study was associated with feeding behaviours and modes of fishes, quantity and quality of food supplied to fishes, differences in stocking densities in farms, different habitats between farm localities and changing volumes and quality of fishpond waters between seasons. Training of farmers on fish farm practices and collaboration with academic and fishery industry partners can have positive influences on hygiene practices and implementation of biosecurity measures with consequent reduction on the prevalence of parasites and improvement in the productivity of the fish farms in the study region.

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