Insight into the diversity of parasites of Cyprinodontiformes (Pisces, Teleostei) from forest streams of South Cameroon, Central Africa, and their potential impact

F D Messu Mandeng, J.-F Agnèse, S. Morand, C F Bilong Bilong

International Journal of Research Studies in Biosciences (IJRSB)
Volume 3, Issue 10, October 2015, PP 97-106
ISSN 2349-0357 (Print) & ISSN 2349-0365 (Online)
www.arcjournals.org

Insight into the diversity of parasites of Cyprinodontiformes (Pisces, Teleostei) from forest streams of South Cameroon, Central Africa, and their potential impact

F. D. Messu Mandeng
Department of Biological Sciences, Higher Teacher Training College,
University of Yaoundé 1,Yaoundé, Cameroon
messumandeng@yahoo.fr

J.-F. Agnèse
Institut des Sciences de l'Evolution, UMR 5554 CNRS, UMR 226 IRD,Université Montpellier 2, Montpellier cedex 5, France
agnese@univ-montp2.fr

S. Morand
CNRS-CIRAD, Centre d'Infectiologie Christophe Mérieux du Laos,
Vientiane, Lao PDR
serge.morand@univ-montp2.fr

C. F. Bilong Bilong
Parasitology & Ecology Laboratory, Dept. of Animal Biology and physiology, University of Yaoundé I, Cameroon
bilong_bilong@yahoo.com

Abstract: *In order to describe the parasite fauna of the Cyprinodontiform fishes from streams located in the forest zone of the central and south plateau and the littoral plain of Cameroon and to evaluate their potential impact on their hosts by analyzing community structures, the gastrointestinal tracts and the gills of 1019 specimens of 14 Cyprinodontiform fish species belonging to the genera Aphyosemion Myers, 1924 and Epiplatys Gill, 1862 were dissected and screened for the presence of parasites. Only 149 fish specimens were found to be infected by at least one of the parasite taxa recovered. On the whole, parasitic infections in cyprinodonts, perceived on the basis of prevalence and mean abundance indices, appeared to be very low, although the parasitic fauna of some host species as A. cameronense was diversified (up to seven species). Aphyosemion cf cameronense, A. koungueense and Aphyosemion sp. showed low abundances and appeared free of ecto- and endoparasites. As micropredators, cyprinodonts acquire these endoparasites through a variety of invertebrate preys and concentrate some infective parasite stages (such as metacercariae) of several definitive hosts that prey on them. This work showed that although nematodes and trematodes, which can develop high intensities or abundances in some fish specimens, might impact their hosts (especially females) and influence their population dynamics, parasitism in general seems not to regulate the communities of the cyprinodont fish species.*

Keywords: *ecology, parasite communities, impact, Aphyosemion, Epiplatys, micropredators.*

1. Introduction

The study of relationships between living organisms and their environment is of great interest, as it encompasses both their physical world and the biotic milieu. Concerning parasitic organisms, their ecology is unique in that the biotic factors of their environment assume a greater and more direct and continuous role than is true for non parasitic species, due to the continual interplay between the biochemistry of the parasite and that of its host [28]. Among vertebrates, fishes represent the most abundant and diversified group and are of great importance and significance for mankind, as they have both economic and aesthetic values that may help raise awareness of the value of conserving aquatic systems [36]. Studies on the ecology of freshwater fish parasites have essentially been conducted in temperate countries [21, 29, 31, 32] while they remain scarce in the tropics [25, 26], especially in Cameroon where those conducted until now were solely based on the analysis of the communities of parasites in a single host species (i.e. component communities) in a single watercourse [5, 37]. However, describing patterns and disclosing processes over a large area and long time periods are undoubtedly targets shared by both human/veterinary epidemiologists and population/community ecologists, and are aimed at integrating heterogeneous data in a consistent framework. Indeed, the spatial and temporal scales of investigations determine the range of patterns and processes that may be detected and therefore the level of understanding and explanation that can be achieved [16]. Forest streams constitute particular ecosystems and abound in several adapted species [30]. Among the fish fauna encountered in the stream ecosystem in the forest zone of south Cameroon are members of the order Cyprinodontiformes, the *Aphyosemion* Myers, 1929 (Nothobranchiinae) and *Epiplatys* Gill, 1962 (Epiplateinae), both genera of the family Aplocheilidae, Bleeker, 1960 [18]. Apart from the work of Birgi and Euzet [7], no investigation has been conducted on the parasite community of these cyprinodonts in Central Africa. The aim of this work was therefore to determine the parasite fauna of these fishes and to evaluate their potential impact on their hosts by analyzing parasite communities in several host species communities.

2. Materials and Methods

2.1. fish sampling

Fishes were collected from December 2011 to February 2014 from 50 forest streams located in central and south plateau and the littoral plain of Cameroon, Central Africa (Fig. 1). Five stations were defined based on the prefectoral administrative zoning. Some sites were visited only once while monitored streams were prospected bimonthly. Fishes caught using a dipnet of 2mm x 2mm mesh size were divided into two batches and immediately transferred into 70% alcohol or in a field freezer. Both conservation methods were used to have the real situation of parasitic infections (prevalence and abundances) in the field at the time of sampling [4]. Fishes were identified after Amiet [2] and Sonnenberg [35].

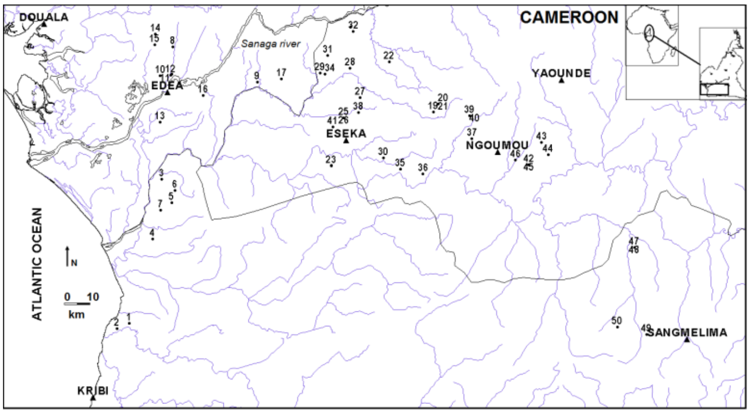

Figure1. *Map of the study area indicating sampling sites of the cyprinodont fishes (DIVA-GIS 7.4.0.1). 1 – Bognoungou, 2 – Namassambi, 3 – Ndoung lo'o, 4 – Pama, 5 – Man ndong, 6 – Mboke, 7 – Ndong medzip, 8 – Nkom, 9 – Hiléba ko'o, 10 – Hiléba Si Makai, 11 – Hiléba Malimba, 12 – Titimba Malimba, 13 – Ndong sone, 14 – Lép si Yap, 15 – Awomakolo, 16 – Lép Si hikôa , 17 – Lép Sô, 18 – Man ngombe, 19 – Hiléba Kombéng, 20 – Lép Ndômbôl, 21 – Man mpan, 22 – Lép manguene, 23 – Diléba diba, 24 – Madjandjan, 25 – Hiléba njék, 26 – Diléba diaa, 27 – Lép So mapan, 28 – Saanda, 29 – Hiléba pem, 30 – Bikout, 31 – Tibda, 32 – Jolibam, 33 – Bobog, 34 – Séa, 35 – Hiléba Yébél, 36 – Makoubé, 37 – Ligen li sôgôl, 38 – Ilanga , 39 – Lép Ngo Bikun 1, 40 – Lép Ngo Bikun 2, 41 – Lép Ndjab, 42 – Bikomna, 43 – Osoe nyada, 44 – Bikok, 45 – Ndikoa, 46 – Ebem Ngama, 47 – Bives, 48 – Ototong, 49 – Man otong, 50 – Avo'o. (NB: points 18, 24 and 33 are respectively too closed to points 12, 23 and 32).*

2.2 Laboratory Analysis

Once in the laboratory and prior to dissection, fishes were measured (only the standard length i.e. the horizontal distance between the snout and the last caudal vertebra of the fish [34] is considered in this work, as some specimens presented damaged caudal fins), weighted and visually sexed (when possible); the sexes were further determined during the dissection of the fish. Then, the fishes' gastrointestinal tract and gills were dissected under a Wild Heerbrugg dissecting microscope for detection of the presence of parasites. It has not been possible to achieve specific identifications for some parasite taxa as trematodes, nematodes and copepods, due to the scarcity and the unavailability of taxonomists of certain zoological groups which is noticed for a long time worldwide [3, 38] and, the ones contacted to help us were not available. Therefore, members of the Trematoda and Nematoda classes were just grouped according to the morphotypes, counted and preserved into ethanol for subsequent studies. Xenomas, located in the skeletal muscle adjacent to the abdominal cavity, were extracted, measured with the microscope micrometer and crushed on a slide to identify the type of spores they contained. Monogenean gill parasites were collected and further examined under a Leica DM2500 microscope (x400) either wet-mounted or after staining in a mixture of glycerin and ammonium picrate [22] for further morphological studies; their identification was done after Birgi and Euzet [7] based on the morphology and size of sclerotized parts of the attachment apparatus (haptor) and genitalia (the vagina and the male copulatory organ).

2.3 Statistical Analyses

In this work, parasite assemblages were examined at higher hierarchical levels (classes) and greater spatial and temporal scales [27]. Failure to discriminate parasite species represented a limit of this study. The numeric weakness of expertise in systematics is a problem noted to the world level; this renders the identification of new species as well as the revision of existing classifications very difficult [3]. Moreover, Wyss and Cherix [38] noted that groups of organisms as viruses, bacteria or some groups of invertebrates as the nematodes are still not well known and would deserve great attention from systematicians; unfortunately, the latter rather tend to disappear to the profit of theoreticians of the environment. Data were analyzed at the community level. Data were analyzed at the community level. The terms mean abundance, intensity and prevalence are defined after [9]. Levels of infection (mean abundance and intensity) were categorized according to [5] i.e. value ≤ 10 is very low, 10 < value ≤ 50 is low, 50 < value ≤ 100 is average and value > 100 is high. The study included all parasites taxa recovered, and mean abundances were computed to be more realistic, as prevalence and intensities of the infections were too low. Two non-parametric abundance-based estimators of species richness, the Chao 1 and the first-order jackknife, and one non-parametric incidence-based estimator of species richness, the second-order jackknife, were used to estimate the potential number of parasite species (observed and unseen) from samples and evaluate the sampling effort which is the ratio between observed species richness and theoretical species richness [23]. These statistical tests were performed with a confidence of 95% using the Paleontological Statistics software PAST 2.17c.

3. RESULTS

3.1. Host Diversity

A total of 1019 fish specimens from 14 species were collected in 50 localities over 150 prospected. These species belonged to the genera *Aphyosemion* Myers, 1924 (Nothobranchiidae, Nothobranchiinae) and *Epiplatys* Gill, 1862 (Nothobranchiidae, Epiplateinae) of the family Aplocheilidae, Bleeker, 1860 (Huber, 2000). They were: *Aphyosemion* (*Chromaphyosemion*) *loennbergii* Boulenger, 1903, *A. koungueense* Sonnenberg, 2007, *A. omega* Sonnenberg, 2007, *A. riggenbachi* Ahl, 1924, *A. ahli* Myers, 1933, *A. raddai* Scheel, 1975, *A. exiguum* Boulenger, 1911, *A. amoenum* Radda and Pürzl, 1976, *A. obscurum* Ahl, 1924, *A. cameronense* Boulenger, 1903, *A. batesii* Boulenger, 1911, *A.* cf *cameronense*, *Aphyosemion* sp. and *Epiplatys* sp. *A. koungueense*, *A.* cf *cameronense* and *Aphyosemion* sp. were particularly poorly sampled (n_i < 20) while the sampling effort of each of the remaining cyprinodont species was relatively high and stood above 58% with that of *A. raddai* having reached 100% (Table1). This sampling effort showed that few cyprinodont species still remain to be caught.

Table1. *Observed and estimated parasite richness (first-order Jackknife) with respective standard deviations and sampling effort of each of the host species*

Cyprinodont host sample			**Parasite**	
Species	**Size**	**Sampling effort (%)**	**Observed richness**	**Jackknife 1 ± SD**
A. ahli	86	63.22	3	4.98 ± 1,39
A. amoenum	71	87.5	3	3.99 ± 0.99
A. batesii	61	69.79	5	7.95 ± 1.68
A. cameronense	133	81.11	7	9.98 ± 1.98
A. cf . *cameronense*	4	-	0	-
A. exiguum	100	92.88	6	6.99 ± 0.99
A. koungueense	5	-	0	-
A. loennbergii	266	58.57	4	6.99 ± 1.78
A. obscurum	46	58.57	4	6.93 ± 1.66
A. omega	85	75.15	5	6.98 ± 1.39
A. raddai	83	100	2	2 ± 0
A. riggenbachi	18	79.17	2	2.94 ± 0.94
Aphyosemion sp.	18	-	0	-
Epiplatys sp.	43	63.22	3	4.95 ± 1.36

3.2. Parasite Diversity

The parasites recovered from the cyprinodont fish species captured belonged to the classes of Nematoda, Trematoda, Monogenea, Ciliophora, Cestoda, Microspora and Copepoda. Parasite taxa (class) richness in infected host species varied from one, in *A. Riggenbachi*, to five, in *A. batesii*, with an average of three classes per host species (Table2).

Table2. *Distribution of parasite taxa as a function of host sex*

Host species	Sample size	Number of parasite taxa (classes)	Sex							
			Male			Female			Undetermined	
			n	parasitized	% infection	n	parasitized	% infection	n	parasitized
A. ahli	86	3	37	5	13.5	35	7	20	14	0
A. amoenum	71	2	49	1	2	20	3	15	2	0
A. batesii	61	5	30	3	10	26	5	19.2	5	1
A.cameronense	133	4	62	24	38.7	62	11	17.7	9	1
A. cf . *cameronense*	4	0	3	0	0	1	0	0	0	0
A. exiguum	100	4	43	6	14	49	7	14.3	8	0
A.koungueense	5	0	5	0	0	0	0	0	0	0
A.loennbergii	266	2	149	10	6.7	86	5	5.8	31	0
A. obscurum	46	2	19	3	15.8	27	3	11.1	0	0
A. omega	85	4	42	12	28.6	17	9	52.9	26	12
A. raddai	83	2	39	2	5.1	42	6	14.3	2	0
A. riggenbachi	18	1	16	5	31.3	1	1	100	1	0
Aphyosemion sp.	18	0	3	0	0	12	0	0	3	0
Epiplatys sp.	43	3	25	4	16	6	3	50	12	0

In *A. cameronense*, three monogenean species were recorded. Microspora were found only in *A. omega*, while trichodinids (Ciliophora) and Cestoda were solely observed respectively in *Epiplatys* sp. on the one hand, *A. ahli* and *A. batesii* on the other hand. *A. loennbergii*, though the most captured fish species, harboured only nematode and trematode parasite species. *A.* cf *cameronense*, *A. koungueense* and *Aphyosemion* sp. appeared free from parasites. The fish species *A. omega*, *A. exiguum*, *A. cameronense* and *A. batesii* harboured the highest number of parasite classes (four to five) and were those on which we found the highest parasite species richness (five to seven) (Table3). Apart from *A. raddai* for which the number of parasitic forms observed is the same as the estimated value (jackknife 1), the parasitic richness observed remained under-estimated. The prevalence of infection and the parasite mean abundance were very low (Table4).

Table3. *Number of parasite species per class and cyprinodont host species*

Host species	Species number of							Total number of parasite species
	Trematode	Nematode	Cestode	Crustacean	Monogenean	Ciliophora	Microspore	
A. ahli	0	1	1	0	1	0	0	3
A. amoenum	2	1	0	0	0	0	0	3
A. batesii	1	1	1	1	1	0	0	5
A.cameronense	2	1	0	1	3	0	0	7
A. cf *cameronense*	0	0	0	0	0	0	0	-
A. exiguum	1	2	0	1	2	0	0	6
A.koungueense	0	0	0	0	0	0	0	-
A. loennbergii	2	2	0	0	0	0	0	4
A. obscurum	2	0	0	1	0	0	0	3
A. omega	2	1	0	1	0	0	1	5
A. raddai	1	1	0	0	0	0	0	2
A. riggenbachi	2	0	0	0	0	0	0	2
Ap hyosemion sp.	0	0	0	0	0	0	0	-
Epiplatys sp.	0	1	0	1	0	1	0	3

Table4. *Prevalence and mean abundances of different parasite forms in the various host species*

Host species (N)	Parasite taxa	Prevalence (%)	Mean Abundance	Standard deviation
A. ahli (86)	Nematoda	11.63	8.37	39.3
	Monogenea			
	Gyrodactylus sp.	1.2	0.01	0.11
Epiplatys sp. (43)	Nematoda	9.3	0.14	0.53
	Copepoda	2.3	0.07	0.46
	Ciliophora	2.3	1.93	12.7
A. loennbergii (266)	Nematoda	4.9	0.1	0.53
	Trematoda			
	Adults	0.4	0.1	1.59
	Metacercariae	0.38	0.06	0.92
A. koungueense (5)	-	-	-	-
A. omega (85)	Nematoda	1.2	0.04	0.33
	Copepoda	1.2	0.01	0.11
	Trematoda			
	Adults	8.2	0.34	2.03
	Metacercariae	28.2	3.27	7.25
	Xenoma	2.4	0.05	0.3
A. riggenbachi (18)	Trematoda			
	Metacercariae	27.8	1.17	2.53
	Adults	5.6	0.06	0.24
A. raddai (83)	Nematoda	6	0.23	1.28
	Trematoda			
	Adults	7.2	0.33	0.93
A. amoenum (71)	Trematoda			
	Metacercariae	2.8	0.03	0.17
	Adults	1.4	0.01	0.12
	Nematoda	2.8	0.03	0.17
A. exiguum (100)	Nematoda	3	0.06	0.42
	Copepoda	2	0.03	0.17
	Trematoda			
	Metacercariae	3	0.53	3.67
	Monogenea	5	0,11	0,66
	Post-larvae	1	0.01	0.1
	Dactylogyrus batesii	2	0.07	0.61
	Cichlidogyrus amieti	2	0.03	0.22
A. cf *cameronense* (4)	-	-	-	-
A. obscurum (46)	Copepoda	2.2	0.02	0.15
	Trematoda			
	Adults	2.2	0.02	0.15
	Metacercariae	6.5	0.26	1.14
	Monogenea			
	Post-larvae	2.2	0.02	0.29
A. cameronense (133)	Trematoda			
	Adults	0.8	0.01	0.09
	Metacercariae	7.5	2	8.34
	Nematoda	2.3	0.64	7.2
	Monogenea	20,30	0,36	1,00
	Post-larvae	3	0.06	0.4
	Cichlidogyrus amieti	12.03	0.2	0.7
	Dactylogyrus batesii	4.5	0.1	0.65
	Gyrodactylus sp.	0.75	0.01	0.09
	Copepoda	2.26	0.02	0.15
A. batesii (61)	Nematoda	1.64	0.02	0.13
	Cestoda	1.64	0.02	0.13
	Copepoda	1.64	0.02	0.13
	Monogenea	6,56	0,23	0,92
	Post-larvae	1.64	0.05	0.38
	Dactylogyrus batesii	4.92	0.18	0.85
	Trematoda			
	Metacercariae	3.3	0.77	5.52

N – number of the fish species captured, irrespective of collection sites.

Nevertheless, when taking the observed maximum intensities into consideration, especially for nematodes and trematodes (adult or metacercarial stages) in host organisms for which 20 ≤ standard length ≥ 28.4 mm with the exception of *Epiplatys* sp. and *A. batesii* that are on average of larger size, one might think that some host individuals may undergo relatively high parasitic pressures as it was the case of an individual of *A. ahli* that harboured 313 nematodes (Table5). Moreover, parasite taxa recovered from the cyprinodonts studied were essentially distributed according to an aggregative mode, for their variances were strictly above the mean abundance of parasite loads.

Table5. *Nematode and trematode maximum intensities in the various host species*

Parameters			Host species										
			Aahl	**Aome**	**Arig**	**Arad**	**Aexi**	**Aobs**	**Acam**	**Aamo**	**Aloe**	**Abat**	***Epiplatys* sp.**
Mean SL (mm)			25.1	22.1	23.5	28.4	20.1	28.2	27.3	27.1	24.8	38.4	36.1
SD			5.2	3.4	4.6	6.3	3.1	6.8	6.0	5.5	4.5	8.8	10.1
Maximum intensity	**Nematode**		313	3	-	11	4	-	83	1	5	1	3
	Trematode	**Adults**	-	18	1	17	-	1	1	1	26	-	-
		Metac	-	38	30	-	28	7	53	1	15	43	-

SD – standard deviation ; SL – standard lenght; Metac – metacercariae ; Aahl – Aphyosemion ahli; Aome – Aphyosemion omega; Arig – Aphyosemion riggenbachi; Arad – Aphyosemion raddai; Aexi – Aphyosemion exiguum; Aobs – Aphyosemion obscurum; Acam – Aphyosemion cameronense; Aamo – Aphyosemion amoenum; Aloe – Aphyosemion loennbergii; Abat – Aphyosemion batesii.

Although the sex of 113 host individuals (11.08% of the total), irrespective of fish species, could not be determined, parasite communities recorded were more present in male hosts than in females in *A. cameronense* (χ^2 = 6.72, ddl=1, P < 0.01). No difference (P > 0.05) was noticed for the other host species [*A. ahli* (χ^2 = 0.54, ddl=1), *Epiplatys* sp. (χ^2_{Yates} = 1.56, ddl = 1), *A. loennbergii* (χ^2 = 0.07, ddl = 1), *A. omega* (χ^2 = 2.34, ddl = 1), *A. exiguum* (χ^2 = 0.002, ddl = 1), *A. amoenum* (χ^2_{Yates} = 2.32, ddl = 1), *A. raddai* (χ^2_{Yates} = 1.01, ddl = 1), *A. obscurum* (χ^2_{Yates} = 0.001, ddl=1), *A. riggenbachi* (χ^2_{Yates} = 0,09, ddl = 1), *A. batesii* (χ^2_{Yates} = 0.37, ddl = 1)].

Among the infected hosts, monogeneans, trichodinids, copepods and even metacercariae (trematodes) were observed on branchial filaments. Trematodes (adults), nematodes and cestodes were found in the digestive tract. Two and one individual nematodes were respectively recovered from the ovaries of *A. exiguum* and *A. loennbergii*. Two xenomas of *Microspridium* sp. were extracted from the skeletal muscle adjacent to the abdominal cavity of an individual of *A. omega*. In most of the cases, host individuals were infected by parasites belonging to a single class with some few exceptions. A case of a monogenean associated with a copepod on the gills of a cyprinodont was found only once on an individual of *A. cameronense*. The class Nematoda was found to parasitize all of the host species except *A. obscurum*.

When considering the hosts' spatial distribution, we found that in an allopatric situation , the host species *A. cf. cameronense*, *A. batesii*, *Aphyosemion* sp., *A. koungueense*, *A. omega*, *A. riggenbachi* and *A. ahli* were free of any parasites. In the other cyprinodonts, infracommunities (at the level of gills and digestive tract) were made up only of parasite of a single class, except for (a) *A. cameronense* that was found infected either by monogeneans and metacercariae or by monogeneans and copepods on the gills, and (b) *A. amoenum* and *A. raddai* where cases of infection by nematodes and adult trematodes were observed. In situation of sympatry, none of the host species were infected simultaneously by organisms of two different classes. *A.* cf. *cameronense* remained uninfected, while *A. cameronense* was infected both at the level of the gills and of the digestive tract (in associations of *A. cameronense* + *A. batesii* + *A. exiguum* on the one hand, and *A. cameronense* + *A. exiguum* on the other hand). This was also the case for *A. omega* and *A. riggenbacchi* (in *A. omega* + *A. riggenbachi* + *Epiplatys* sp. association), *Epiplatys* sp. (in *A. ahli* + *A. loennbergii* + *Epiplatys* sp. association) and *A. obscurum* (in *A. exiguum* + *A. obscurum*). In this situation, *Epiplatys* sp. increased its parasite species richness especially by recruiting nematodes.

4. DISCUSSION

In the forest zone of south Cameroon, the cyprinodont fauna of streams is diversified [2] and new species are still being discovered [1]. Among all the cyprinodont fish species studied, the sample size of A. cf cameronense, A. koungueense and Aphyosemion sp. were very low due to the fact that their biotopes were prospected just once during the time period of this work. These three fish species also appeared free from ecto- and endoparasites s.l. in their respective sites. One could evoke strong regulation of parasites due to host resistance, although Combes [13] stated that this phenomenon is rare for macroparasites. Moreover, at the level of our study we could not identify behavioural adaptations that allow host to avoid parasites. In the geographical area prospected, parasites (e.g. monogeneans) often show some seasonal occurrence [4, 5, 6]. However, all the other sites were frequently visited and did not show any clear seasonal parasite occurrence. In the large majority of cases, parasite richness is not due to randomness but rather results from multiple factors [13]. For all host species, the observed parasitic richness was most likely underestimated. The first-order jackknife estimator and the sampling effort also confirmed that more new parasite and host species are still to be discovered in our study area. Actually, the south plateau was incompletely explored. Some areas like Ebolowa, where Amiet [2] reported the presence of Aphyosemion hertzogi Radda, 1975 and Aphyosemion halleri Radda and Pürzl, 1976 were not prospected.

The prevalence of infection and the parasitic mean abundance were in general very low, in the sense of Bilong Bilong and Njine [5], although the maximum intensities especially for nematodes and trematodes (metacercariae) revealed that some host individuals may undergo relatively high parasitic pressures. Brosset [8] suspected that, more than predation, parasitism could be the main regulatory factor of the populations of cyprinodonts of the Ivindo basin (Gabon). As far as this biotic factor is concerned, our findings suggest that nematodes (and somewhat trematodes), which can develop high intensities or abundances in some fish individuals, are precisely bioagressors that can provoke hosts' mortality and influence their population dynamics.

While cestodes were only found once in A. ahli and A. batesii, nematodes and trematodes (adults and cysts) affected almost all of the host species except A. obscurum and A. riggenbachi for nematodes and A. ahli and Epiplatys sp. for trematodes. The relatively high frequency of host infection by nematodes could be correlated to the high diversity of these organisms and to their various transmission modes [33, 28, 10, 14]. As micropredators, cyprinodonts acquire these parasites through a variety of food and concentrate some infective parasite stages (metacercariae) of further definitive hosts that prey on them, as is the case of the trout-perch (Percopsis omiscomaycus, Percopsidae) from Dauphin Lake, Mannitoba, Canada [24].

The fact that some fish species were not infected by some parasite taxa cannot be attributed to a weak sampling effort, but probably to local environmental (abiotic and biotic) conditions still to be determined. Poulin [27] and Combes [13] mentioned that, except for some types of hosts or parasites, local processes are likely to be more important determinants of species richness than regional ones. These authors added that in general, the physical or biological characteristics of the habitat, combined with various historical events leading to gains or losses of parasite species, will influence the local availability of species parasite and shape component communities. In this study, several non exclusive hypotheses (hosts' limits of biocenose, hosts' ethological filters, parasites' angle of requirement, parasites' angles of immune break, among others) [15, 17, 11, 12, 13] could also explain the absence of nematodes in A. obscurum and A. riggenbachi, trematodes in A. ahli and Epiplatys sp., and monogeneans in several fish species.

Nematodes were found in the ovaries of A. exiguum and A. loennbergii. In his synthesis on the ecology of parasites, Rohde [28] underlined that in some cases many parasites affect the reproductive organs of fish and it seems possible that they may reduce the number of offspring and regulate fish populations. This study involved 1019 individuals of several cyprinodont fish species, but only three specimens did harbour nematodes in their ovaries. Therefore, the impact of this type of parasitism seems to be negligible. Other nematodes were found in the digestive tract often at low or very low intensities. They probably do not impact their hosts. For instance, Kabata [17] stated that adult nematodes (coelozoic forms) rarely cause serious injury. At most they cause local lesions of low significance. However, heavy nematode infections, especially in small and young fishes, may be more serious. Adult trematode intensities were also low while infection by metacercariae, in some host specimens, was in average. Adult trematodes are often harmless while individual fish harbouring larval trematodes may suffer tissue damage [17].

Two xenomas were extracted from the skeletal muscle of the abdominal cavity of a single individual of A. omega. The scarcity of this observation suggests that this type of infection does not impact in our environment, although it is known that microsporidians, myxosporidians and helminthes provoke traumas, compressions and irritations on their hosts [20].

5. CONCLUSION

This study underlined that the Cyprinodontiform fauna is diversified (14 species) in the central and south plateau and the littoral plain of Cameroon, Central Africa. It was also the case for the parasitic fauna (up to seven species) of some host species (A. cameronense). Among these parasites, nematodes and trematodes are those, by decreasing order of importance, that could potentially provoke hosts' mortality, due in certain circumstances to their intensities (e.g. 313 nematode individuals in an A. ahli specimen), and therefore regulate their host populations, especially females. Being micropredators preying on small invertebrates, these fishes are predisposed to nematode and trematode infections. It would be interesting to follow the dynamics of these host-parasite systems in relation to waters' physical and chemical variables and hosts' diet, in a locality where these hosts live in sympatry, using a monthly observation.

ACKNOWLEDGEMENT

The authors would like to thank the IRD (Institut de Recherche pour le Développement) through the project "Programme Pluridisciplinaire Régional: Forêts Tropicales Humides d'Afrique Centrale" (PPR FTH-AC) for funding the field part of this work.

REFERENCES

[1] Agnèse J.-F., Legros O., Cazaux B. and Estivals G., (2013) *Aphyosemion pamaense*, a new killifish species (Cyprinodontiformes: Nothobranchiidae) from Cameroon, *Zootaxa*, 3670, 516–530.

[2] Amiet J.-L., (1987) *Faune du Cameroun. 2- Le genre Aphyosemion Myers (Pisces, Teleostei, Cyprinodontiformes).* 262 pp. Sciences Nat. Compiègne.

[3] Anonyme, (2000) Ordonner la diversité du vivant, Rapport de l'Académie des Sciences, rst n°11 ; 258p. Ed Tec and Doc, Paris.

[4] Bilong Bilong, C.F. (1995) *Les Monogènes parasites des poissons d'eau douce du Cameroun : biodiversité et spécificité ; biologie des populations inféodées à Hemichromis fasciatus*. 341 pp. Thèse de Doctorat d'Etat, Université de Yaoundé I, Cameroun.

[5] Bilong Bilong, C.F. and Njiné T. (1998) Dynamique de population de trois Monogènes parasites d'*Hemichromis fasciatus* Peters, 1858 dans le Lac Municipal de Yaoundé et intérêt possible en pisciculture intense. Annales de la Faculté des Sciences Université de Yaoundé I, Série Sciences Naturelles et Vie 34, 295–303.

[6] Bilong Bilong, C.F. and Tombi, J. (2005) Temporal structure of a component community gill parasites of *Barbus martorelli* Roman, 1971 (Freshwater Cyprinidae) in the centre province, Cameroon. *Cameroonian Journal of Biology and Biochemistry Sciences* 13, 9–18.

[7] Birgi, E. and Euzet, L. (1983) Monogènes parasites des poissons des eaux douces du Cameroun. Présence des genres *Cichlidogyrus* et *Dactylogyrus* chez *Aphyosemion* (Cyprinodontidae). *Bulletin de la société zoologique de France* 108, 10 –106.

[8] Brosset, A. (1982) Le peuplement des Cyprinodontes du bassin de l'Ivindo, Gabon. *La Revue d'Ecologie (La Terre et la Vie)* 36, 233–292.

[9] Bush, A.O., Lafferty, K.D., Lotz, J.M. and Shostak, A.W. (1997) Parasitology meets ecology on its own terms: Margolis *et al*., revisited. *Journal of Parasitology* 89, 575–583.

[10] Cassier, P., Brugerolle, G., Combes, C., Grain, J. and Raibaut, A. (1998) *Le parasitisme, un équilibre dynamique.* 366 pp. Enseignement des sciences de la vie. Masson, Paris.

[11] Combes, C. (1990) Rencontre, identification, installation dans le cycle des métazoaires parasites. *Bulletin de la société zoologique de France* 115, 99–105.

[12] Combes, C. (1991) Evolution of parasite life-cycles. pp. 62–82 *in* Toft, C.A., Aeschlimann, A. and Bolis, L. (Eds) *Parasite-Host Associations: Coexistence or Conflict?*

[13] Combes, C. (2001) *Parasitism. The ecology and evolution of intimate interactions*. 728 pp. The University of Chicago Press, Chicago and London,

[14] Dajoz, R. (2000) Mésoclimats et microclimats. Leur influence sur les êtres vivants. pp. 59–86 *in* Dajoz (ed) Dunod, 7e edn, *Précis d'écologie*.

[15] Euzet, L. and Combes, C. (1980) Les problèmes de l'espèce chez les animaux parasites. pp 239–285 *in* Mémoires de la société zoologique de France "*Les Problèmes de l'espèce dans le règne animal*" 40.

[16] Giraudoux, P., Raoul, F., Pleydell, D. and Craig, P.S. (2008) Multidisciplinary studies, Systems approaches and parasite eco-epidemiology: something old, something new. *Parasite* 15, 469–476.

[17] Holmes, J.C. (1986) The structure of the helminth communities. *International Journal of Parasitology* 17, 203–209.

[18] Huber, J.H. (2000) *Killi-Data 2000. Updated checklist of taxonomic names, collecting localities and bibliographic references of oviparous Cyprinodont fishes (Cyprinodontiformes)*. 538 pp. Cybium, Société Française d'Ichtyologie Ed. Paris.

[19] Kabata, Z. (1985) *Parasites and diseases of fish cultured in the tropics*. 318 pp. Taylor and Francis, London and Philadelphia.

[20] Kinkelin, P., Michel, C. and Ghittino, P. (1985) *Précis de pathologie des poissons*. 348 pp. INRA-OIE. Paris.

[21] Koskivaara, M., Valtonen, E.T. and Vuori, K.M. (1992) Microhabitat distribution and coexistence of *Dactylogyrus* species (Monogenea) on the gills of roach. *Parasitology* 104, 273–281.

[22] Malmberg, G. (1957) On the occurence of *Gyrodactylus* on Swedish fishes. *Skrifter utgivna av Södra Sveriges Fiskeriföreningen* 1957, 19–76.

[23] Mokam, D.G., Djiéto-Lordon, C. and Bilong Bilong, C.F. (2014) Patterns of species richness and diversity of insects associated with cucurbit fruits in the southern part of Cameroon. *Journal of Insect Science* 14, doi 10.1093/jisesa/ieu110.

[24] Nelson, P.A. and Dick, T.A. (1986) Actors shaping the parasite communities of trout-perch, *Percopsis omiscomaycus* Walbaum (Osteichthyes: Percopsidae), and the importance of scale. *Canadian Journal of Zoology* 80, 1986–1999.

[25] Obiekezie, A.I. (1991) The principal pathogens and diseases of cultured fishes in Nigeria. pp 197–207 *in* Koop, K. (Eds) *Aquaculture in Africa*.

[26] Olurin, K.B. and Somorin, C.A. (2006) Intestinal helminthes of the fishes of Owa Stream, South-West Nigeria. *Research Journal of Fish and Hydrobiology* 1, 6–9.

[27] Poulin, R. (1998) *Evolutionary ecology of parasites: from individuals to communities*. 1st edn. 212 pp. Chapman and Hall, 2–6 Boundary Row. London SE1 8HN, UK.

[28] Rohde, K. (1993) *Ecology of Marine Parasites*. 2nd edn. 298 pp. CAB International, Oxford.

[29] Sasal, P. and Morand, S. (1998) Comparative analysis: a tool for studying monogenean ecology and evolution. *International Journal for Parasitology* 28, 1637–1644.

[30] Schneider, J.B. (2007) Plaidoyer pour une restauration des cordons rivulaires naturels des ruisseaux et ruisselets forestiers. *Forêt wallone* 86, 43–57.

[31] Šimková, A., Kadlec, D., Gelnar, M. and Morand, S. (2002a) Abundance-prevalence relationship of gill congeneric ectoparasites: testing for core-satellite hypothesis and ecological specialization. *Parasitology Research* 88, 682–686.

[32] Šimková, A., Ondrackova, M., Gelnar, M. and Morand S. (2002b) Morphology and coexistence of congeneric ectoparasite species: reinforcement of reproductive isolation? *Biological Journal of the Linnean Society* 76, 125–135.

[33] Smith, J.D. (1985) Nematoda: general account. pp 295-352 *in* Hodder and Stoughton (2nd edn) Introduction to animal parasitology.

[34] Stiassny, M.L.J., Teugels, G.G., Carl, D. and Hopkins, C.D. (2007) *Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale*. 603 pp. Vol. 2. Paris, IRD, MnHn, MRAC.

[35] Sonnenberg, R., (2007) Description of three new species of the genus *Chromaphyosemion* Radda, 1971 (Cyprinodontiformes: Nothobranchiidae) from the coastal plains of Cameroon with a preliminary review of the *Chromaphyosemion splendopleure* complex. *Zootaxa* 1591, 1–38.

[36] Tejerina-Garro, F.L., Maldonado, M., Ibañez, C., Pont, D., Roset, N. and Oberdorff, T. (2005) Effects of Natural and Anthropogenic Environmental Changes on Riverine Fish Assemblages: a Framework for Ecological Assessment of Rivers. *Brazilian Archives of Biology and Technology* 48, 91–108.

[37] Tombi, J., Bilong Bilong, C.F. and Morand S. (2011) Gill ectoparasites of *Barbus martorelli* (Teleostean: Cyprinidae) from a tropical watercourse (Cameroon, Africa): conflict or coexistence? *Parasite* 18, 71–78.

[38] Wyss, C. and Cherix, D. (2013). *Traité d'entomologie forensique. Les insectes sur la scène de crime. 2e édition revue et augmentée.* 326p. Collection Sciences Forensiques. Presses polytechniques et universitaires normandes.

AUTHORS' BIOGRAPHY

F. D. Messu Mandeng, is a researcher (Animal Biology, Parasitology and Ecology) in the Department of Animal Biology and Physiology, Faculty of Sciences, University of Yaoundé I, and an assistant lecturer in the department of Biological Sciences of the Higher Teacher Training College of the same university in Cameroon.

J. –F. Agnèse, Research Director, IRD-ISEM, Montpellier, France. Areas of research: Population genetics, Phylogeny, Aquaculture.

S. Morand, Research Director, focuses his research on the evolutionary ecology of host-parasite interactions and health ecology. Field parasitologist, he is concerned at the role of biodiversity as risks and insurance for emerging infectious diseases. He is conducting projects on the impacts of global changes on the links between biodiversity and health. Serge Morand belongs to the French CNRS and CIRAD and actually based in Laos at the"Centre Christophe Mérieux d'Infectiologie du Laos".

C. F. Bilong Bilong, Professor, Head of department of Animal Biology and Physiology, Faculty of Sciences, University of Yaoundé I, Cameroon. Areas of research: Taxonomy, Ecology, Parasitology, Host-Parasite relationships, Epidemiology.