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Int. J. Biol. Chem. Sci. 12(2): 749-768, April 2018

ISSN 1997-342X (Online), ISSN 1991-8631 (Print)

International Journal of Biological and Chemical Sciences

Original Paper http://ajol.info/index.php/ijbcs http://indexmedicus.afro.who.int

Spatial distribution of monogenean gill parasites of *Parachanna obscura* (Günther, 1861) – Channidae – in Lake Ossa (Edéa, Cameroon)

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ABSTRACT

Parasites are a danger for fish even more in natural environment than in farming conditions. Knowledge of their biology of is important for prevention. The objective of this study was to investigate the distribution of monogenean gill community of *Parachanna obscura* (Pisces, Channidae). Monogenean species were identified using the morphology of haptoral and genital sclerotized parts. Appropriate statistical tests were used to compare prevalence and intensity of parasites. In Lake Ossa (south Cameroon), *P. obscura* individuals were in relatively good condition (K = 1,4±0,15) although they were infected by five monogenean species (*Eutrianchoratus magnus*, *E. minutus*, *E. imbachi*, *E. chibami* and *E. malleus*). Male and female fish harbor similar parasite intensity. There was not statistical difference in the infection patterns of different host sizes, although big or old fish seemed to accumulate parasites over time. The distribution of helminthes on the gills did not revealed host side preference. There is no evidence of competition between species of *Eutrianchoratus* in their distribution areas, but the filaments of different gill arches exert a progressive (antero-posterior) sifting effect on the infecting larvae. This study proves once again that in natural environment parasite intensities are very low or low and this state minimizes competition between monogeneans species.

Keywords: Ancyrocephalidae, *Eutrianchoratus*, sifting effect, prevalence, intensity, fish.

INTRODUCTION

Channidae, formerly Ophiocephalidae, are cylindrical perciform fishes found in Africa and Asia. Their accessory breathing organ, in the form of two pharyngeal supra-branchial chambers, enables them to utilize atmospheric air and survive out of water for considerable periods. A single genus, *Parachanna* (Teugels and Daget, 1984) is present in Africa with three species represented in Lower Guinea (Teugels, 2007), among which two, *P. africana* (Steindadener, 1879) and *P. obscura* (Gunther, 1961), are found in Cameroon. *Parachanna obscura*, also named “snakehead”, is a synonym of *Channa obscura*, *C. obscurus*, *Paraophiocephalus obscurus*, *Paraphicephalus obscurus* and *Ophiocephalus obscurus*. It is distributed from the Zaïre basin through West Africa, as from the Senegal River in the West

DOI: https://dx.doi.org/10.4314/ijbcs.v12i2.11

to the Nile in the East (Stiassny et al., 2007; Teugels, 2007). It is a piscivorous/predatory fish which lives in the bank vegetation of the main river channel or in the vegetated (swampy) areas in the flood plain, pools and lagoons (Olasunkanmi and Ipinmoroti, 2014). It has been used or studied for use in African aquaculture (Odo et al., 2011) like others african native fish (Zango et al., 2016; Mukabo Okito et al., 2017) and to regulate cichlid populations (Kpogue et al., 2013). This robust and tolerant species reproduces throughout the year with a peak during or just after rainfall (Whenu and Fagade, 2012; Kpogue et al., 2013). It reaches a maximum size of 455 mm total length (Teugels, 2007; Vodounnou et al., 2017) and therefore represents a good source of survival proteins; moreover its delicious flesh is appreciated by local populations.

The gill filaments of *P. obscura* in the Nyong basin (Cameroon) are parasitized by five monogenean species (Bilong Bilong, 1995): *Eutrianchoratus magnus* (Paperna, 1969); *E. minutus* (Paperna, 1969); *E. imbachi* (Dossou and Euzet, 1984); *E. chibami* (Bilong Bilong, et al., 1994); and *E. malleus* (Bilong Bilong et al., 1994). The ecological aspects of the parasitism of this host by these ancyrocephalids remain unstudied. In fact, fish parasites form interesting and little-used subjects for studies on communities and their ecology (Lekeufack Folefack and Fomena, 2013; Tombi et Bilong Bilong, 2013). The main objectives of this study was to provide informations on some ecological aspects of the monogenean gill community of *Parachanna obscura* by investigating how these parasitic helminthes exploit their hosts.

MATERIALS AND METHODS

Study area

Specimens of *P. obscura* were caught using gill nets from July to November 2014 during the rainy season in Lake Ossa (3°45'42'' - 3°53'N; 9°58'' - 10°04'E) (Figure 1), located 20 km to the west of the city of Edéa and 30 km from the Atlantic Ocean (Bahanak et al., 2016).

Sampling methods

Fish captured were immediately immerged in a 10% formalin solution to fix monogeneans *in situ* and prevent their loss due to abundant host post-mortem excretion of mucus (Bilong Bilong, 1995). After few minutes, a 1 cm abdominal buttonhole (incision) was realized on each specimen to later identify its sex. Fishes were then transported to the laboratory for parasite and host investigations.

Methods and data collection tools

In the laboratory, the standard length of each fish specimen was measured in millimeters (mm); the latter was then immerged in tap water to reduce formalin contamination. Gill arches from both the right and left sides, numbered I to IV in the antero-posterior direction, were removed separately and placed in different labeled Petri dishes containing tap water.

Monogeneans were dislodged from the gill filaments with a needle under stereoscopic microscope. They were stained in-between slides and cover slips into a drop of haematoxylin eosin (Bilong Bilong, 1986), then identified at 40x magnification under a microscope after Paperna (1969), Dossou and Euzet (1984) and Bilong Bilong et al. (1994) by the morphology and size of sclerotized pieces of the haptor and copulatory organs. In this transverse analysis, the terms prevalence, intensity (I), mean intensity (MI) and abundance are defined after Bush et al. (1997), infracommunity and xenocommunity after Combes (1995), transverse gradient after Rohde (1977), core and satellite species after Kooskivaara and Valtonen (1991), common, intermediate and rare species after Valtonen et al. (1997). The mean intensity (even the intensity) is categorized in our environment as follows: very low ($MI \leq 10$), low ($10 < MI \leq 50$), average ($50 < MI \leq 100$) and high ($MI > 100$) after Bilong Bilong and Njiné (1998). Parasitic individuals typically exhibit an aggregated distribution among available host specimens such that most of the latter harbor no or few parasites and few hosts harbor many parasites (Rõzsa et al., 2000); therefore the prevalence and mean intensity are respectively given with confidence interval or bootstrap confidence limits to 95% probability.

Data analysis

The index of discrepancy D quantifies the difference between an observed parasite distribution and a hypothetical distribution that corresponds to the ideal case where all hosts harbor the same number of parasites. It measure the concept of aggregation as intuitively perceived by most parasitologists (Poulin, 1998). The prevalences were compared using Fisher's exact test and mean intensities by a bootstrap test or by Mood's medium test. APS statistical comparisons were realized using the QP30 software (Rõzsa et al., 2000; Reiczigel et al., 2005). The parasites overlap at the level of the gill arch, sector and zone (Figure 2) was estimated using the Forbes index followed by Khi-2 test. The Forbes index measures the deviation of an association at random: F = 1 means that parasites are randomly associated; f = 2 means that the association of the species is twice more favorable than fortuity; F<1 means that the parasites association is less than predicted chance. Differences were considered as significant when P < 0.05. Analyses concerned only core and secondary species. Since in a community satellite or rare species are little or no structuring (Holmes, 1987; Combes, 1995).

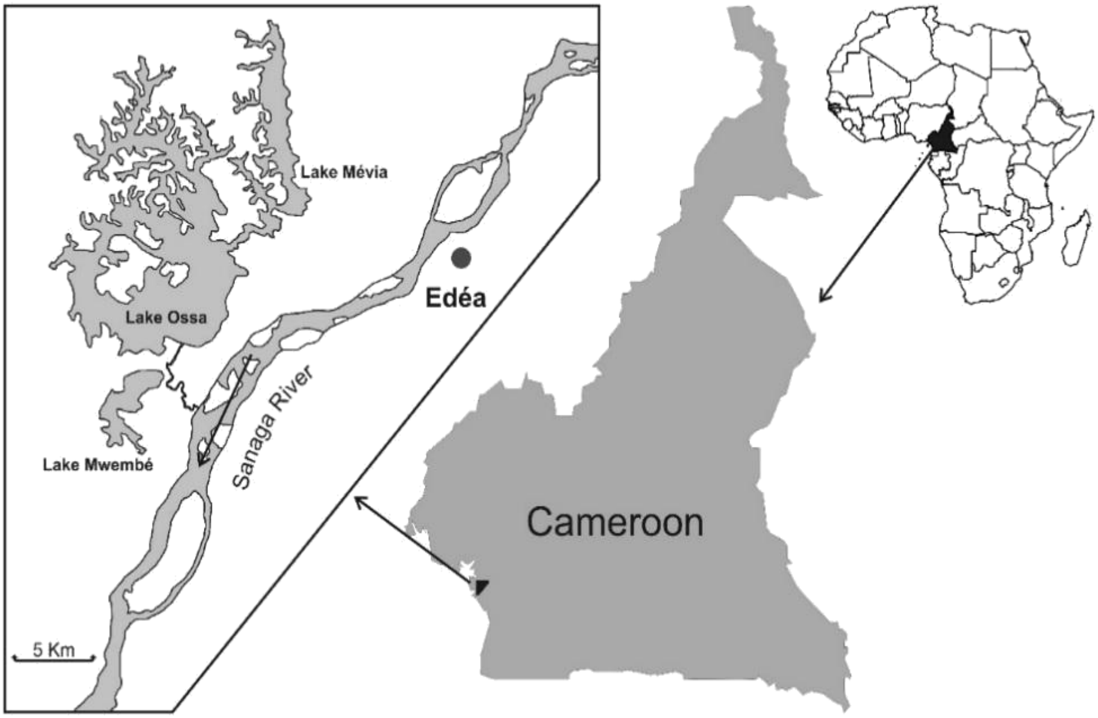


Figure1: Geographic localization of Lake Ossa (After Bahanak et al., 2016 modified).

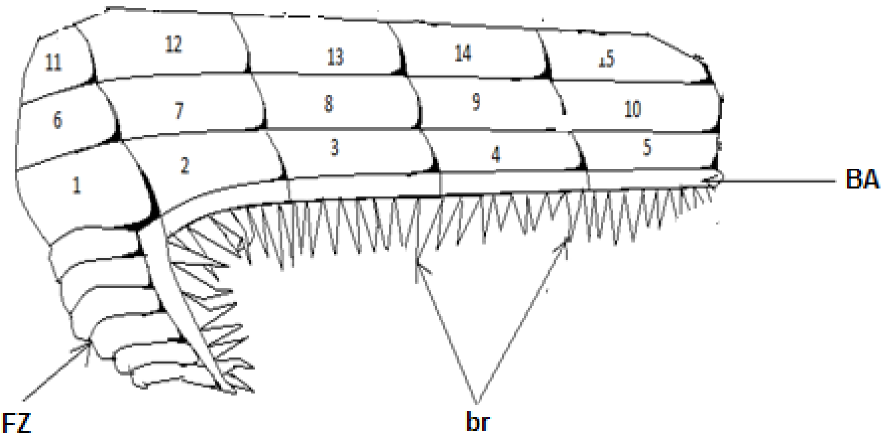


Figure 2: Sectoral and zonal delimitation of gill areas of *Parachanna obscura.*
Legend: 1 to 15 = stations; 1, 6, and 11 = stations of the dorsal sector; 2,7 and 12 = stations of the medio-dorsal sector; 3, 8 and 13 = stations of the median sector; 4, 9 and 14 = stations of the medio-ventral sector; 5, 10 and 15 stations of the ventral sector; 1,2,3,4 and 5: basal zone; 6,7,8,9 and 10 median zone; 11, 12, 13, 14 and 15 distal zone; BA = bone arch; br = branchiospines; ZF = fibrous zone.

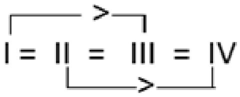
RESULTS

A total of 50 specimens (30 females, 20 males: sex-ratio = 1.5) of *Parachanna obscura* were examined. Their standard length ranged from 200 to 300 mm. Fish were generally in good physiological condition since their condition factor K was averagely 1.40 (1.17 – 1.71) ± 0.15. At least 9847 monogeneans were collected from this fish sample: 4694 *Eutrianchoratus minutus* (47.7%), 3278 *E. imbachi* (33.3%), 1610 *E. chibami* (16.3%), 246 *E. malleus* (2.5%) and 19 *E. magnus* (0.2%). The prevalence (prev.), mean intensity and discrepancy index (D) of these parasite species are summarized in Table 1. No difference was found in the infection between male and female hosts, either for prevalences or mean intensities (Table 2). At the xenocommunity level, only one fish individual was found free of any parasite species (Prev. = 98.00% (89.35 - 99.89), the mean number (MN) of helminthes per infected host = 100.65; D = 0.462). The highest number of monogeneans harbored by a specimen of *P. obscura* was 403. As a function of the length classes, MN = 77.61 (54.43 - 122.96) for the host length class [200 - 250[, MN = 123.81 (88.33 - 172.38) for host length class [250 - 300[and MN = 109.60 (44.80 - 221.80) for host length class [300 - 350[. These mean values were not significantly different (P = 0.301), even if hosts of the length class [250 – 300[averagely seemed to accumulate more helminth individuals. This was the pattern for *E. chibami* and *E. imbachi*, while for *E. minitus* the mean parasitic load significantly (P = 0.001) increased up to the highest level in the host length class [300 – 350[(Table 3). No side effect was noticed in the infection of *P. obscura* either for the rate of parasitism or the mean number of parasites per infected side (Table 4). Based on this result, the study of monogenean distribution in the transverse gradient had therefore considered indifferently only one side per fish.

Distribution at the level of arches

The Mood's median test comparing median intensities revealed statistical differences between gill arches only for *E. chibami* (P = 0.000), *E. imbachi* (P = 0.004) and *E. minitus* (P= 0.003) (Table 5). Therefore the comparison continued only with these three species. *Eutrianchoratus minitus* and *E.*

imbachi concentrated antero-posteriorly on gill arches with the following pattern

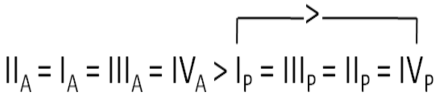


$$I = II = III = IV$$

As for *E. chibami*, although there was a significant difference between the four gill arches, the multiple comparisons did not show any difference, its distribution pattern was I = II = III = IV (Table 6).

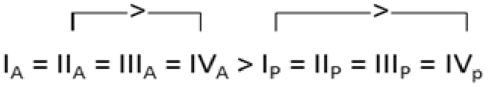
Distribution at the hemibranches level

For *E. minitus*, the anterior hemibranches were statistically equally colonized (prevalence). But, anterior hemibranches were more exploited than the posterior ones (Table 7a). The pattern of gill occupation of this monogenean species was:



$$II_A = I_A = III_A = IV_A > I_P = III_P = II_P = IV_P$$

Similarly, the abundance of this helminth species didn’t significantly vary between anterior hemibranch in the one hand, and posterior hemibranch in the other hand (Table 7b). But, the parasitism decreases slightly in the antero-posterior direction as the following model:

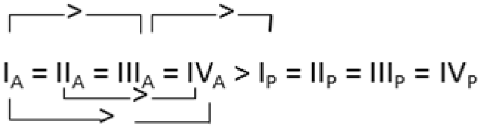


$$I_A = II_A = III_A = IV_A > I_P = II_P = III_P = IV_p$$

For *E. imbachi*, the prevalence analysis (Table 7c) also showed that the anterior hemibranches on one hand and the posterior hemibranches on the other hand were statistically similarly colonized. However, the anterior hemibranches are more occupied than the posterior ones. The pattern of occupation was:

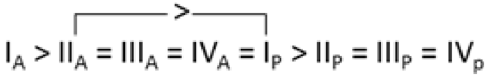
$$II_A = I_A = III_A = IV_A > I_P = III_P = II_P = IV_P$$

The study of abundance of this monogenean species also revealed the antero-posterior model of colonization and, the posterior hemibranches harbored less parasites (Table 7d). The model of the infection was:



$$I_A = II_A = III_A = IV_A > I_P = II_P = III_P = IV_P$$

This was the same for *E. chibami*. The model of infection according with the prevalence (Table 7e) was:



$$I_A > II_A = III_A = IV_A = I_P > II_P = III_P = IV_p$$

While that according with the abundance was:

$$I_A = II_A = III_A = IV_A = I_P > II_P = III_P = IV_p$$

The posterior hemibranches of arch I harbored the same number of *E. chibami* individuals than the anterior hemibranch of arch IV (Table 7f).

At the sectorial level, for many parasitic pairs, the values of the Forbes Index were not very different from the unity. Therefore, these parasitic associations seem to occur randomly. Nevertheless, the co-occurrence of the pairs *E. minitus* / *E. imbachi* (sector 5: arches 3 and 4), *E. minitus* / *E. chibami* (sector 1: arch 4; sector 2: arch 4; sector 3: arch 2; sector 5: arches 2 and 3) and *E. imbachi* / *E. chibami* (sector 1, arch3; sector 2; arch 3; sector 4: arch 4) was higher than predicted (Table 8).

At the zonal level, for the different pairs of parasitic species, the values of the Forbes index were close to 1 showing that in most cases the distribution of these parasites was done at random, except for pairs: *E. minitus* / *E. imbachi* (basal zone: arch 4), *E. minitus* / *E. chibami* (median zone: arc 3, basal zone: arc 4), and *E. imbachi* / *E. chibami* (distal zone: arc 1, 3 and 4) where positive associations seemed more frequent than predicted (Table 9). *Eutrianchoratus minitus* concentrated much more in the median zone of arches 1, 2, 3 and less in arch 4 (basal and dorsal areas).

Table 1: Prevalence and mean intensity of monogenean species of *P. obscura*.

Parasite species	Prevalence (CI)	Mean Intensity (BC)	Discrepancy index (D)
E. chibami	90.0 (78.18 – 96.68)	17.89 (11.11 – 35.60)	0.623
E. imbachi	98.0 (89.35 – 99.95)	33.45 (25.71 – 44.00)	0.501
E. magnus	24.0 (13.06 – 37.17)	1.58 (1.17 – 1.92)	0.794
E. malleus	58.0 (43.20 – 71.82)	4.24 (3.03 – 5.72)	0.669
E. minutus	96.0 (86.28 – 99.52)	48.90 (37.63 – 65.42)	0.496

CI: confidence interval; BC: bootstrap confidence limit.

Table 2: Prevalence and mean intensity of monogenean species as a function of *P. obscura* sex.

Parasites species	Prevalence		Mean intensity		T value	P value	
	M	F	M	F		Fisher's exact test	Bootstrap T Test
E. chibami	91.7	85.7	11.33	35.92	1.341	0.611	0.275
E. imbachi	97.2	100	36.89	24.86	1.485	1.000	0.158
E. magnus	27.8	14.3	1.50	2.00	-2.236	0.468	0.124
E. malleus	61.1	50.0	4.00	5.00	-0.639	0.534	0.520
E. minutus	92.9	97.2	51.35	42.31	0.623	0.486	0.558

M: male, F: female.

Table 3: Mean Intensity as a function of host size class.

Parasite species	Host size (mm)		
	[200 – 250]	[250 – 300]	[300 – 350]
E. minutus	MI = 34.50 ; n = 22	MI = 59.9; n = 21	MI = 69.0; n = 5
E. imbachi	MI = 33,15; n = 23	MI = 34,29; n = 21	MI = 31.40; n = 5
E. chibami	MI = 9.90; n = 21	MI = 29.42; n = 19	MI = 7.60; n = 5
Infracommunity	MN = 77.61; n = 23	MN = 123.81; n = 21	MN = 109.60; n = 5

MN: mean number; MI: mean intensity; n: number of fishes.

Table 4: Prevalence and mean intensity of monogenean species as a function of host side

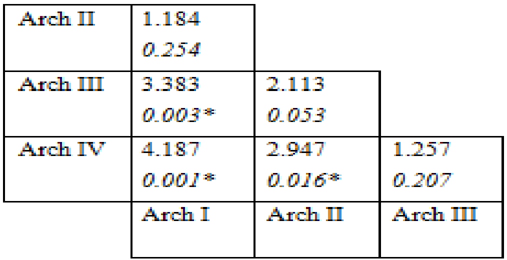
Parasites species	Prevalence		Mean intensity		T value	P value	
	R	L	R	L		Fisher's exact test	Bootstrap T test
E. chibami	80.0	88.0	10.70	8.57	0.497	0.414	0.646
E. imbachi	92.0	94.0	17.00	18.23	-0.336	1.000	0.744
E. magnus	16.0	14.0	1.25	1.29	-0.145	1.000	0.776
E. malleus	44.0	48.0	2.26	2.96	-0.983	0.841	0.343
E. minutus	92.0	94.0	25.52	24.96	0.107	1.000	0.909

R = right side, L = left side.

Table 5: Infection rate and mean parasites load of P. *obscura* per arch.

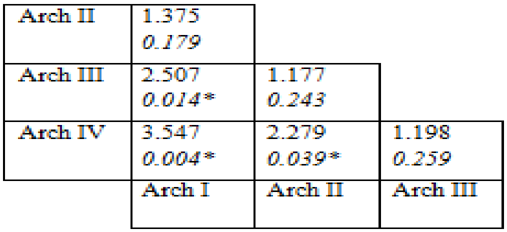
Parasite species	Arch	Infection rate (%)	Parasite		P-value	
			Mean number	Medium	Fisher	Mood's médian test
E. chibami	I	80.0	9.95	5.0		
	II	76.0	5.39	2.5	0.036	0.000
	III	58.0	3.59	2.0		
	IV	60.0	3.27	2.0		
E. imbachi	I	88.0	13.82	10.5		
	II	86.0	10.33	7.0	0.658	0.004
	III	88.0	7.86	5.5		
	IV	80.0	6.03	4.0		
E. magnus	I	10.0	1.2	1.0		
	II	6.0	1.0	1.0	0.702	0.515
	III	12.0	1.0	1.0		
	IV	6.0	1.33	1.0		
E. malleus	I	36.0	1.94	1.5		
	II	38.0	1.74	1.0	0.744	0.393
	III	34.0	2.18	2.0		
	IV	28.0	1.29	1.0		
E. minutus	I	90.0	20.38	13.0		
	II	92.0	15.61	10.0	0.692	0.003
	III	88.0	9.27	6.5		
	IV	84.0	7.24	6.0		

Table 6: Multiple comparison of mean parasite loads between arches.



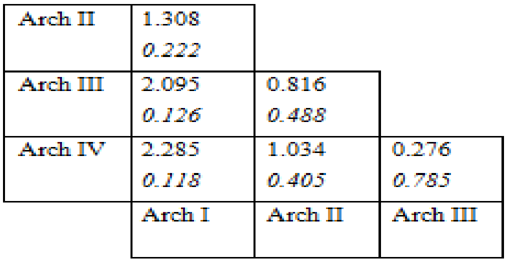
Arch II	1.184 *0.254*		
Arch III	3.383 *0.003**	2.113 *0.053*	
Arch IV	4.187 *0.001**	2.947 *0.016**	1.257 *0.207*
	Arch I	Arch II	Arch III

a) *E. minutus*



Arch II	1.375 *0.179*		
Arch III	2.507 *0.014**	1.177 *0.243*	
Arch IV	3.547 *0.004**	2.279 *0.039**	1.198 *0.259*
	Arch I	Arch II	Arch III

b) *E. imbachi*



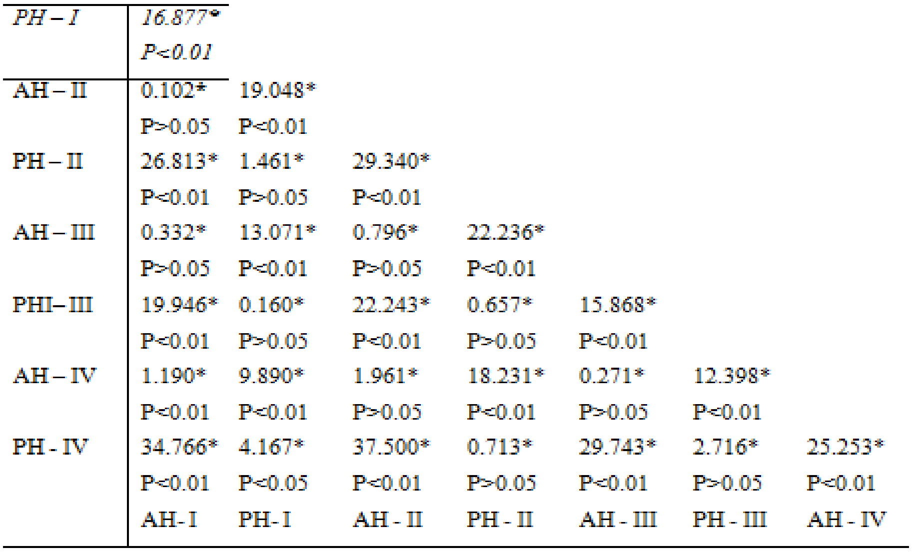
Arch II	1.308 *0.222*		
Arch III	2.095 *0.126*	0.816 *0.488*	
Arch IV	2.285 *0.118*	1.034 *0.405*	0.276 *0.785*
	Arch I	Arch II	Arch III

c) *E. chibami*

Legend: T values followed by the P values in italics *: P value < 0.05

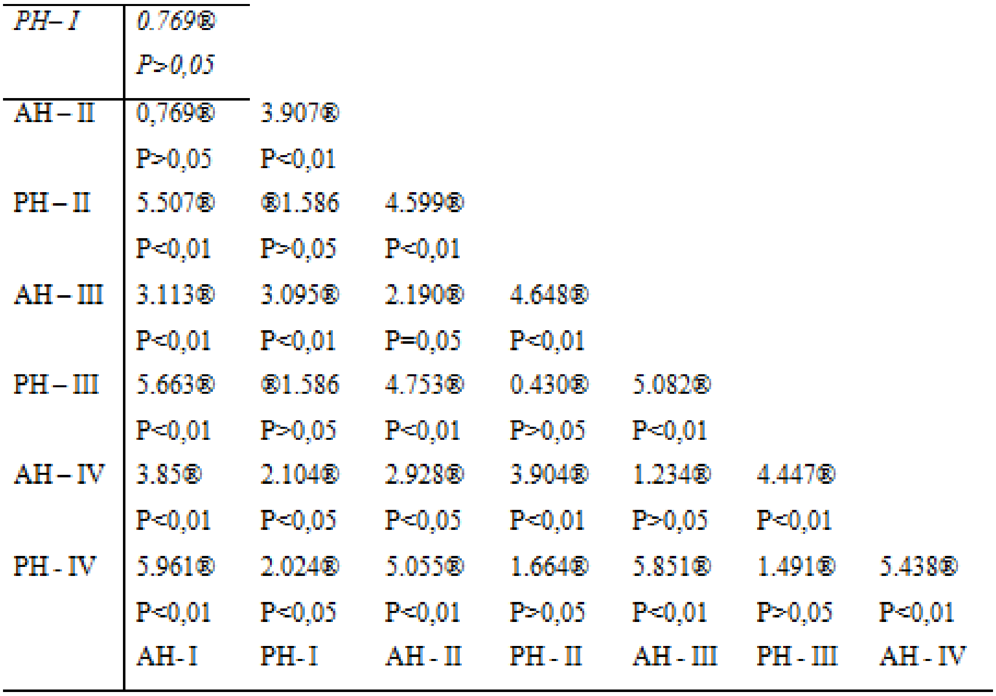
Table 7: (*****) Khi-2 values, (®) t- value for bootstrap test and P-value comparing prevalence and mean abundance: For *E. minitus* (**a, b)**; For *E. imbachi* (**C, d)** and For *E. chibami* (**e, f)** for anterior and posterior hemibranchias (AH and PH).

a)



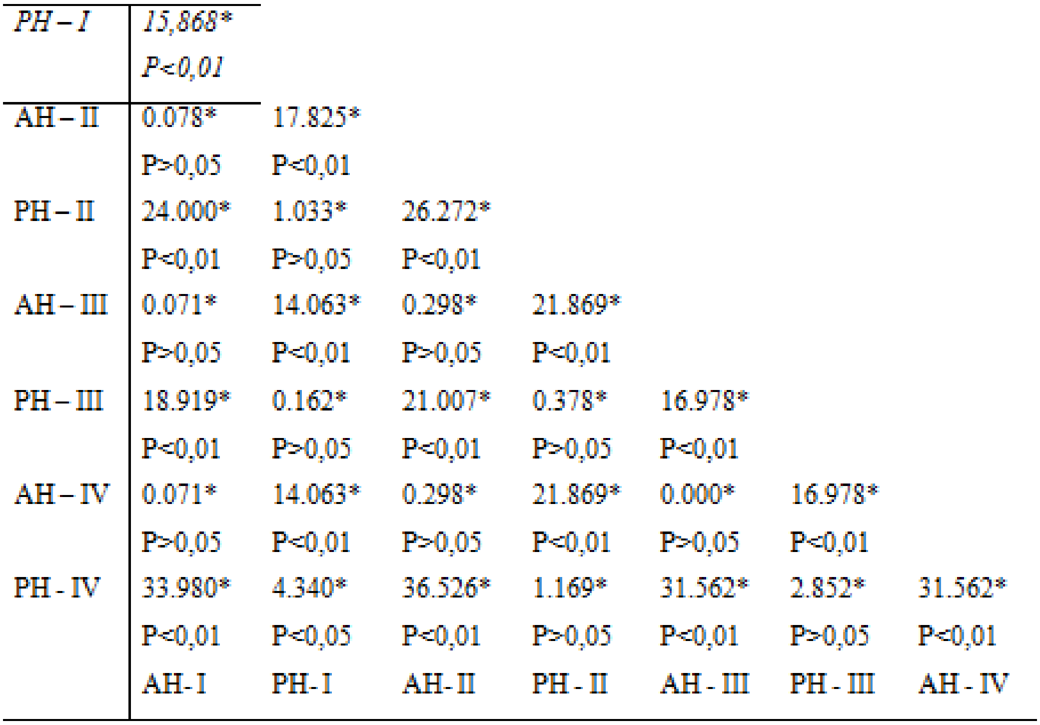
PH – I	*16.877** *P<0.01*						
AH – II	0.102* P>0.05	19.048* P<0.01					
PH – II	26.813* P<0.01	1.461* P>0.05	29.340* P<0.01				
AH – III	0.332* P>0.05	13.071* P<0.01	0.796* P>0.05	22.236* P<0.01			
PHI– III	19.946* P<0.01	0.160* P>0.05	22.243* P<0.01	0.657* P>0.05	15.868* P<0.01		
AH – IV	1.190* P<0.01	9.890* P<0.01	1.961* P>0.05	18.231* P<0.01	0.271* P>0.05	12.398* P<0.01	
PH - IV	34.766* P<0.01	4.167* P<0.05	37.500* P<0.01	0.713* P>0.05	29.743* P<0.01	2.716* P>0.05	25.253* P<0.01
	AH- I	PH- I	AH - II	PH - II	AH - III	PH - III	AH - IV

b)



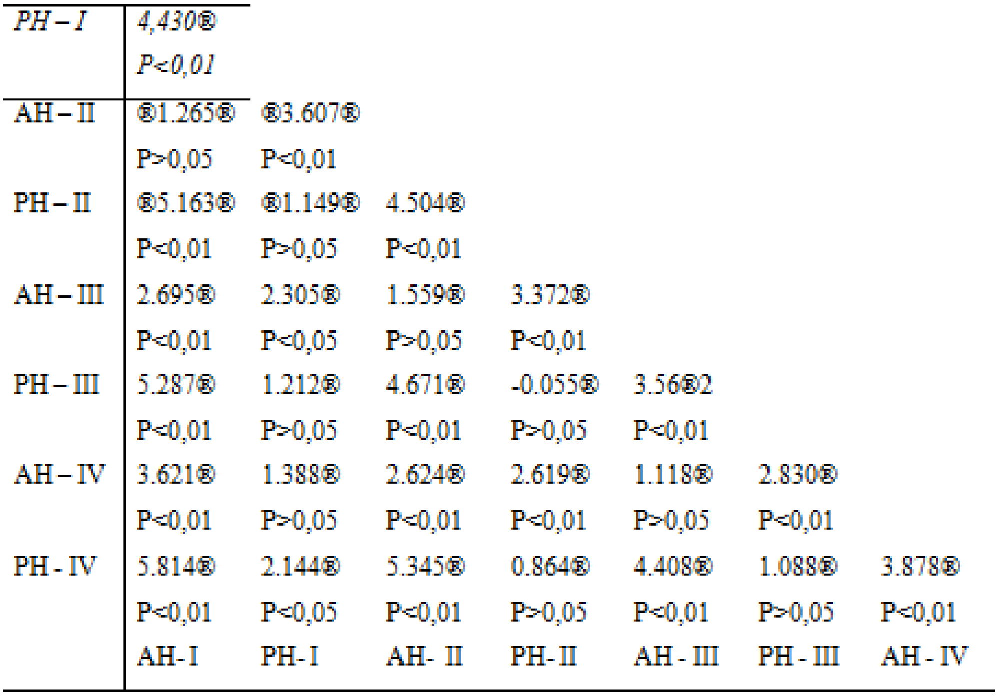
PH– I	*0.769®* *P>0,05*						
AH – II	0,769® P>0,05	3.907® P<0,01					
PH – II	5.507® P<0,01	®1.586 P>0,05	4.599® P<0,01				
AH – III	3.113® P<0,01	3.095® P<0,01	2.190® P=0,05	4.648® P<0,01			
PH – III	5.663® P<0,01	®1.586 P>0,05	4.753® P<0,01	0.430® P>0,05	5.082® P<0,01		
AH – IV	3.85® P<0,01	2.104® P<0,05	2.928® P<0,05	3.904® P<0,01	1.234® P>0,05	4.447® P<0,01	
PH - IV	5.961® P<0,01	2.024® P<0,05	5.055® P<0,01	1.664® P>0,05	5.851® P<0,01	1.491® P>0,05	5.438® P<0,01
	AH - I	PH - I	AH - II	PH - II	AH - III	PH - III	AH - IV

c)



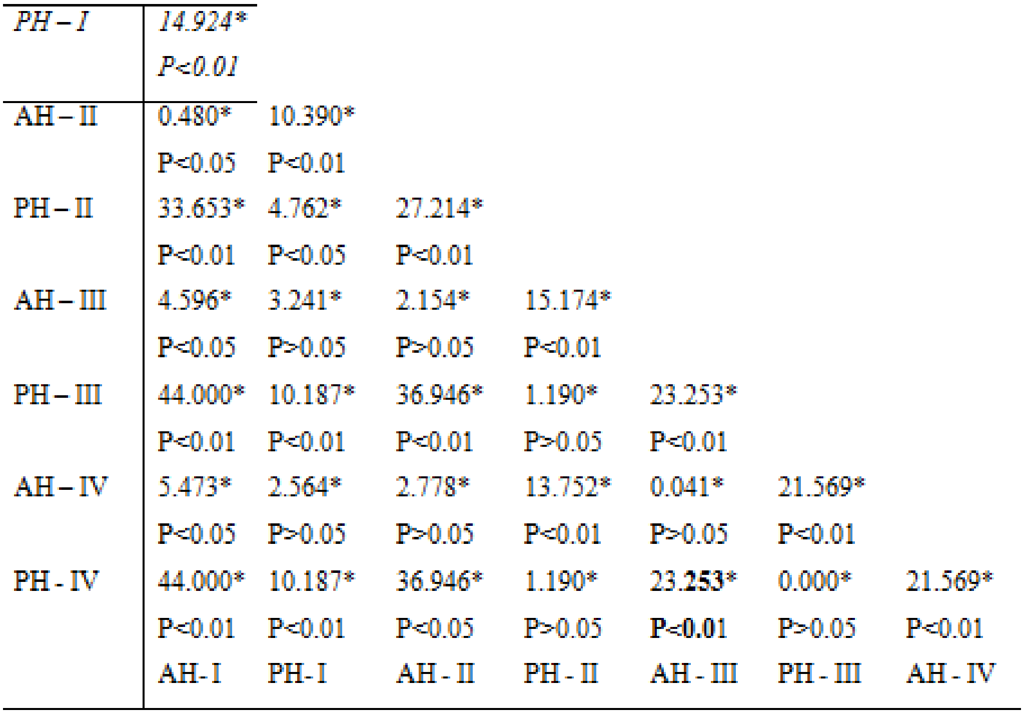
PH – I	*15,868** *P<0,01*						
AH – II	0.078* P>0,05	17.825* P<0,01					
PH – II	24.000* P<0,01	1.033* P>0,05	26.272* P<0,01				
AH – III	0.071* P>0,05	14.063* P<0,01	0.298* P>0,05	21.869* P<0,01			
PH – III	18.919* P<0,01	0.162* P>0,05	21.007* P<0,01	0.378* P>0,05	16.978* P<0,01		
AH – IV	0.071* P>0,05	14.063* P<0,01	0.298* P>0,05	21.869* P<0,01	0.000* P>0,05	16.978* P<0,01	
PH - IV	33.980* P<0,01	4.340* P<0,05	36.526* P<0,01	1.169* P>0,05	31.562* P<0,01	2.852* P>0,05	31.562* P<0,01
	AH - I	PH - I	AH - II	PH - II	AH - III	PH - III	AH - IV

d)



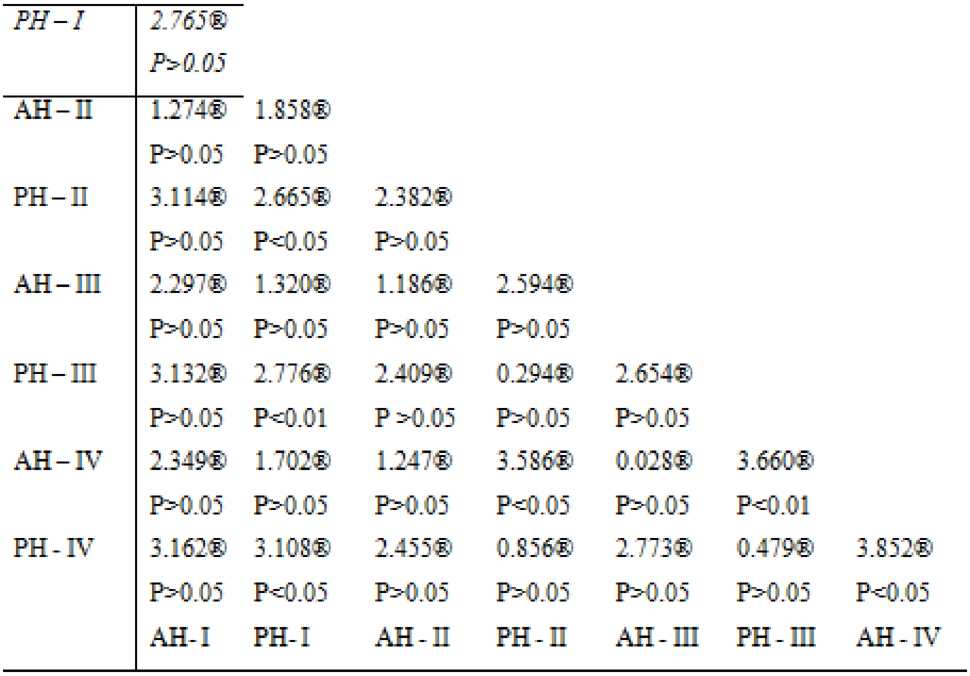
PH – I	*4,430®* *$P<0,01$*						
AH – II	®1.265® $P>0,05$	®3.607® $P<0,01$					
PH – II	®5.163® $P<0,01$	®1.149® $P>0,05$	4.504® $P<0,01$				
AH – III	2.695® $P<0,01$	2.305® $P<0,05$	1.559® $P>0,05$	3.372® $P<0,01$			
PH – III	5.287® $P<0,01$	1.212® $P>0,05$	4.671® $P<0,01$	-0.055® $P>0,05$	3.56®2 $P<0,01$		
AH – IV	3.621® $P<0,01$	1.388® $P>0,05$	2.624® $P<0,01$	2.619® $P<0,01$	1.118® $P>0,05$	2.830® $P<0,01$	
PH - IV	5.814® $P<0,01$	2.144® $P<0,05$	5.345® $P<0,01$	0.864® $P>0,05$	4.408® $P<0,01$	1.088® $P>0,05$	3.878® $P<0,01$
	AH- I	PH- I	AH- II	PH- II	AH - III	PH - III	AH - IV

e)



PH – I	*14.924** *$P<0.01$*						
AH – II	0.480* $P<0.05$	10.390* $P<0.01$					
PH – II	33.653* $P<0.01$	4.762* $P<0.05$	27.214* $P<0.01$				
AH – III	4.596* $P<0.05$	3.241* $P>0.05$	2.154* $P>0.05$	15.174* $P<0.01$			
PH – III	44.000* $P<0.01$	10.187* $P<0.01$	36.946* $P<0.01$	1.190* $P>0.05$	23.253* $P<0.01$		
AH – IV	5.473* $P<0.05$	2.564* $P>0.05$	2.778* $P>0.05$	13.752* $P<0.01$	0.041* $P>0.05$	21.569* $P<0.01$	
PH - IV	44.000* $P<0.01$	10.187* $P<0.01$	36.946* $P<0.05$	1.190* $P>0.05$	23.**253*** **$P<0.01$**	0.000* $P>0.05$	21.569* $P<0.01$
	AH- I	PH- I	AH - II	PH - II	AH - III	PH - III	AH - IV

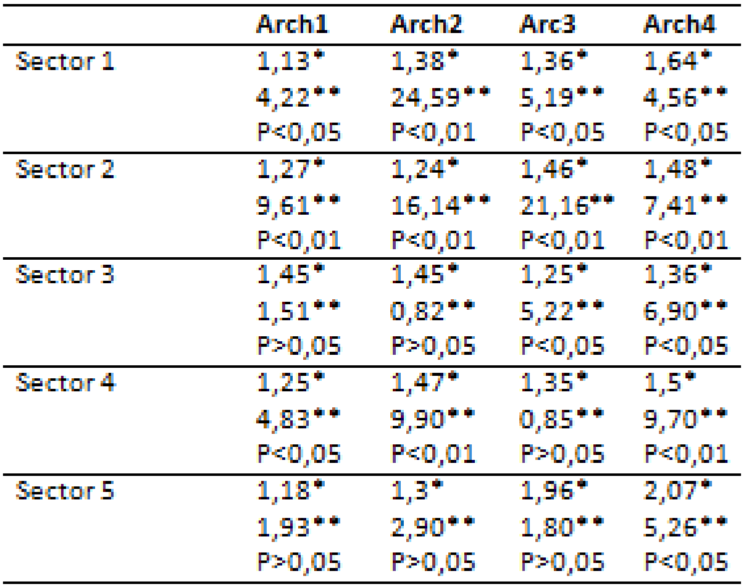
f)



PH – I	*2.765®* *P>0.05*						
AH – II	1.274® P>0.05	1.858® P>0.05					
PH – II	3.114® P>0.05	2.665® P<0.05	2.382® P>0.05				
AH – III	2.297® P>0.05	1.320® P>0.05	1.186® P>0.05	2.594® P>0.05			
PH – III	3.132® P>0.05	2.776® P<0.01	2.409® P >0.05	0.294® P>0.05	2.654® P>0.05		
AH – IV	2.349® P>0.05	1.702® P>0.05	1.247® P>0.05	3.586® P<0.05	0.028® P>0.05	3.660® P<0.01	
PH - IV	3.162® P>0.05	3.108® P<0.05	2.455® P>0.05	0.856® P>0.05	2.773® P>0.05	0.479® P>0.05	3.852® P<0.05
	AH - I	PH - I	AH - II	PH - II	AH - III	PH - III	AH - IV

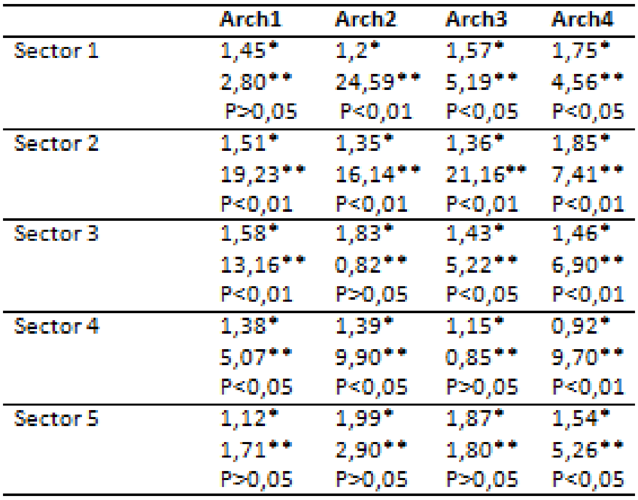
Table 8: (*) Forbes Index, (**) Khi-2 and *P* values comparing prevalence of the combinations of pairs of the three principal parasites species of *P*. *obscura***.**

a) *E. minitus / E. imbachi*



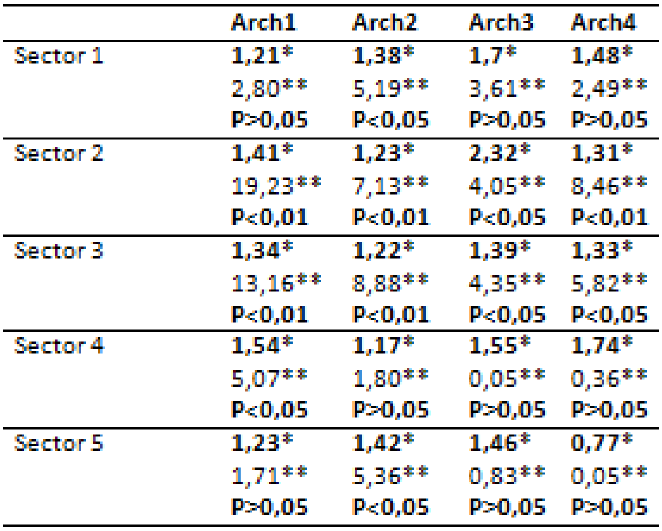
	Arch1	Arch2	Arc3	Arch4
Sector 1	1,13* 4,22** P<0,05	1,38* 24,59** P<0,01	1,36* 5,19** P<0,05	1,64* 4,56** P<0,05
Sector 2	1,27* 9,61** P<0,01	1,24* 16,14** P<0,01	1,46* 21,16** P<0,01	1,48* 7,41** P<0,01
Sector 3	1,45* 1,51** P>0,05	1,45* 0,82** P>0,05	1,25* 5,22** P<0,05	1,36* 6,90** P<0,05
Sector 4	1,25* 4,83** P<0,05	1,47* 9,90** P<0,01	1,35* 0,85** P>0,05	1,5* 9,70** P<0,01
Sector 5	1,18* 1,93** P>0,05	1,3* 2,90** P>0,05	1,96* 1,80** P>0,05	2,07* 5,26** P<0,05

b) *E. minitus* / *E. chibami*



	Arch1	Arch2	Arch3	Arch4
Sector 1	1,45* 2,80** P>0,05	1,2* 24,59** P<0,01	1,57* 5,19** P<0,05	1,75* 4,56** P<0,05
Sector 2	1,51* 19,23** P<0,01	1,35* 16,14** P<0,01	1,36* 21,16** P<0,01	1,85* 7,41** P<0,01
Sector 3	1,58* 13,16** P<0,01	1,83* 0,82** P>0,05	1,43* 5,22** P<0,05	1,46* 6,90** P<0,01
Sector 4	1,38* 5,07** P<0,05	1,39* 9,90** P<0,05	1,15* 0,85** P>0,05	0,92* 9,70** P<0,01
Sector 5	1,12* 1,71** P>0,05	1,99* 2,90** P>0,05	1,87* 1,80** P>0,05	1,54* 5,26** P<0,05

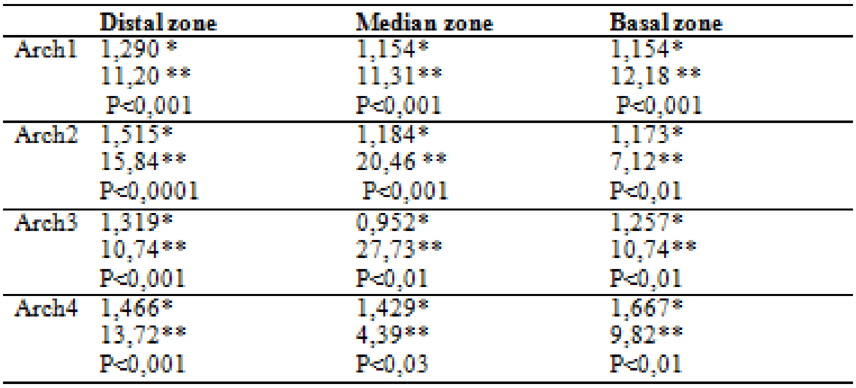
c) *E. imbachi* / *E. chibami*



	Arch1	Arch2	Arch3	Arch4
Sector 1	**1,21*** 2,80** **P>0,05**	**1,38*** 5,19** **P<0,05**	**1,7*** 3,61** **P>0,05**	**1,48*** 2,49** **P>0,05**
Sector 2	**1,41*** 19,23** **P<0,01**	**1,23*** 7,13** **P<0,01**	**2,32*** 4,05** **P<0,05**	**1,31*** 8,46** **P<0,01**
Sector 3	**1,34*** 13,16** **P<0,01**	**1,22*** 8,88** **P<0,01**	**1,39*** 4,35** **P<0,05**	**1,33*** 5,82** **P<0,05**
Sector 4	**1,54*** 5,07** **P<0,05**	**1,17*** 1,80** **P>0,05**	**1,55*** 0,05** **P>0,05**	**1,74*** 0,36** **P>0,05**
Sector 5	**1,23*** 1,71** **P>0,05**	**1,42*** 5,36** **P<0,05**	**1,46*** 0,83** **P>0,05**	**0,77*** 0,05** **P>0,05**

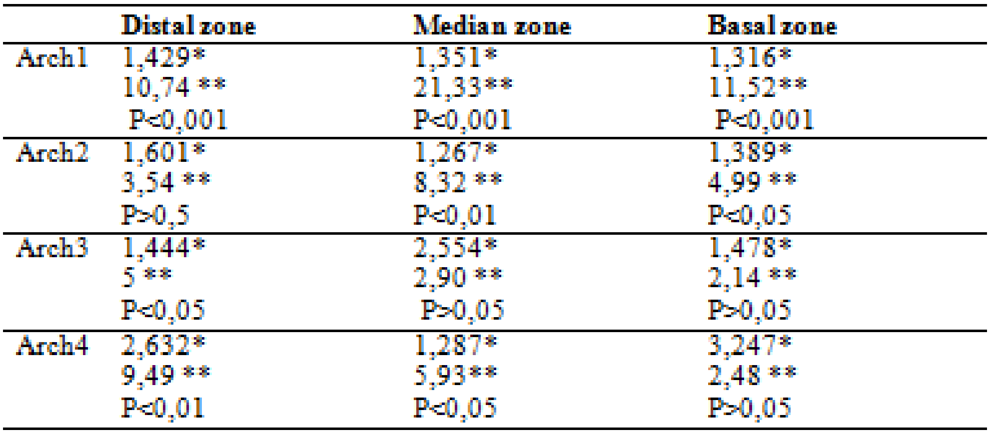
Table 9: (*) Forbes index, (**) Khi-2 and *P* values comparing pairs parasites prevalences per gill arch zones: **a)** *E. minitus* vs *E. imbachi*; **b**) *E. minitus vs E. chibami ;* **c)** *E. imbachi* vs *E. chibami.*

a.



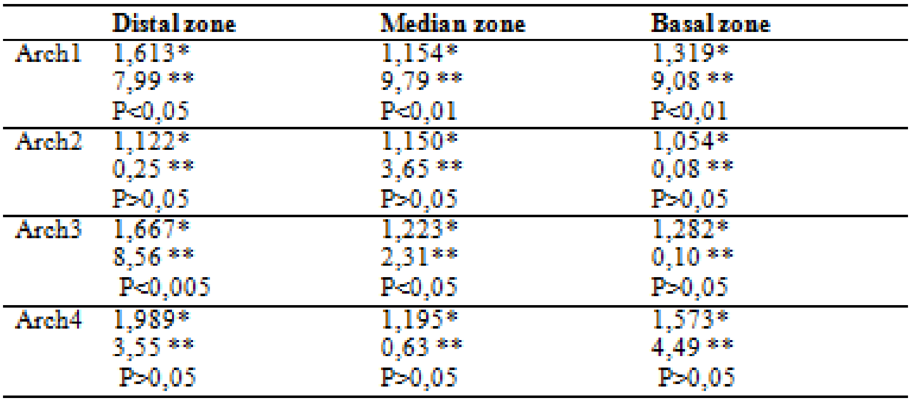
	Distal zone	Median zone	Basal zone
Arch1	1,290 * 11,20 ** P<0,001	1,154* 11,31** P<0,001	1,154* 12,18 ** P<0,001
Arch2	1,515* 15,84** P<0,0001	1,184* 20,46 ** P<0,001	1,173* 7,12** P<0,01
Arch3	1,319* 10,74** P<0,001	0,952* 27,73** P<0,01	1,257* 10,74** P<0,01
Arch4	1,466* 13,72** P<0,001	1,429* 4,39** P<0,03	1,667* 9,82** P<0,01

b.



	Distal zone	Median zone	Basal zone
Arch1	1,429* 10,74 ** P<0,001	1,351* 21,33** P<0,001	1,316* 11,52** P<0,001
Arch2	1,601* 3,54 ** P>0,5	1,267* 8,32 ** P<0,01	1,389* 4,99 ** P<0,05
Arch3	1,444* 5 ** P<0,05	2,554* 2,90 ** P>0,05	1,478* 2,14 ** P>0,05
Arch4	2,632* 9,49 ** P<0,01	1,287* 5,93** P<0,05	3,247* 2,48 ** P>0,05

c.



	Distal zone	Median zone	Basal zone
Arch1	1,613* 7,99 ** P<0,05	1,154* 9,79 ** P<0,01	1,319* 9,08 ** P<0,01
Arch2	1,122* 0,25 ** P>0,05	1,150* 3,65 ** P>0,05	1,054* 0,08 ** P>0,05
Arch3	1,667* 8,56 ** P<0,005	1,223* 2,31** P<0,05	1,282* 0,10 ** P>0,05
Arch4	1,989* 3,55 ** P>0,05	1,195* 0,63 ** P>0,05	1,573* 4,49 ** P>0,05

DISCUSSION

Five species: *E. magnus*, *E. minutus*, *E. imbachi*, *E. chibami* and *E. malleus* were recorded on the gill filaments of *P. obscura* caught in Lake Ossa, Sanaga Basin. This monogenean richness is similar to the finding of Bilong Bilong et al. (1994) in the Nyong Basin; it confirms the host interchanges between Cameroonian river systems (Thys van den Audenaerde, 1966) which favor not only parasites' transfers (Nack et al., 2015) but also their geographical dispersal.

This parasitism by five congeneric species raises the question of arch partitioning; it also suggests that sympatric speciation is more common than thought and that competition is not the main community structuring force, for it allows similar ecological species to coexist (Lim, 1990). Fish polyparasitism by monogeneans is quite well documented (Boungou et al., 2008; Ibrahim, 2012; Tombi et al., 2014). It is related to many parameters such as sampling effort (Walter et al., 1995), host and parasite phylogenies (Zharikova, 2000), ecology (Zharikova, 2000), water quality (Galli et al., 2001) and vacant niches due to low parasites load (Nack et al., 2018). In this work *E. magnus* and *E. malleus* with prevalence of 24% and 58% respectively had very low mean intensities (< 10); they are therefore considered satellite species. *Eutrianchoratus chibami* and *E. imbachi* were common (Prev ≥ 90%) but their mean intensities were low (< 35); they are considered intermediate. The common *E. minutus* (Prev = 96%), although having a low mean intensity (48.9), is considered the core species in this xenocommunity. Therefore, in the Lake Ossa environment, though their prevalence was somewhat high, all these monogenean species mean intensities were very low or low. This fact suggests the absence of competition among these parasites due to their small size when compared with the gill area of the host (Paperna, 1982) and the prevailing low intensity of infection (Tombi and Bilong Bilong, 2004; Nack et al., 2010). Similarly, Šimková and Rohde (2013) stated since vacant niches are available, interspecific competition is unimportant for freshwater and marine gill parasites of fishes. *Parachanna obscura* individuals captured in Lake Ossa appeared in good condition since their condition factor K was averagely 1.40 (Froese, 2006); this proves that in this natural environment, parasite specific loads were below dangerous thresholds. In fact, under normal circumstances, although monopisthocotyleans do cause epidermal lesions on their fish hosts, the resulting damage is negligible since fish possess high regenerative abilities (Kinkelin et al., 1985; Kabata, 1985; Cheng, 1986). Paperna (1982) summarized that in fish species with a fast growth [case of *P. obscura* (Teugels, 2007)], the tissue response makes rapid parasite spreading difficult, and that, from a length of 35 to 38 mm, the gill filaments may harbor high parasite load because the fish acquire good immunity to eliminate them. This statement also relativizes the impact of some high parasite loads observed in this work at the component community level, although the seasonal approach of the intensity still remains unstudied.

Males and females *P. obscura* were similarly infected (prevalence and mean intensity) probably because both sexes live in the same environment (Welcomme and Merona, 1988) and are equally exposed and susceptible to oncomiracidia. Although there was no statistical difference in the infection among host length classes, our findings on *E. minutus* suggests that big/large or old fish accumulate monogeneans over time and consequently represent the parasitic source or reservoir for young individuals (Cable et al., 2002; Blahoua et al., 2009; Ibrahim, 2012; Tombi et al., 2014).

For the right and left body sides, it is suggested that the bilateral symmetric body of this fish and its parasite species support the evenness of the parasite loads of both sides (Soylu et al., 2013). Rohde (1993) related one side fish preference by parasites to the body asymmetry of the host. The symmetric distribution of monogenean gill parasites is a well-documented phenomenon (Nack et al., 2010; Tombi et al., 2010; Soylu et al., 2013), while asymmetric distribution is scarce (Hendrix, 1990).

The mean number of the core (*E. minutus*) and the intermediate (*E. imbachi*) species decreased antero-posteriorly from arch I to arch IV, while for the second intermediate species (*E. chibami*), this parasite load was the same from arch I to arch IV. Concerning the variation of the mean number of the core and the intermediate species, our results are similar to those of Tombi et al. (2014) for monogenean gill parasites of *Oreochromis niloticus*, Jerônimo et al. (2013) for monogenean gill parasites of the hybrid patinga, on the first three gill arches when compared with gill arch IV, and Starruscu - Bedivan et al. (2008) who noticed that the gill arch I of *Barbus meridionalis* was more infected by *Paradiplozoon tisae*. In many other cases, monogenean parasites prefer the two median arches II and III (Tombi et al., 2014). Conversely in Cameroon, Nack et al. (2010) found that *Quadriacanthus* sp. and *Birgiellus kellensis*, gill monogeneans of the catfish *Clarias camerunensis*, prefer arch IV rather than arch I. Many hypotheses have been proposed to explain the gill arch preference by monogeneans on teleosts. Authors like Lo and Morand (2001) argued that the median arches are more infected because of the large volume of water flowing through them, while Buchmann (1989) and Koskivaara and Valtonen (1991) associated this preference to the large surface of colonization offered to parasites. Lo and Morand (2001) previously explained this phenomenon by parasite load which induces the competition and thus the gill selection. Koskivaara and Valtonen (1992) and Guttiérrez and Martorelli (1994) also suggested that the host immunity can influence the microhabitat selection. In the present work, all parasite species had broader niches in the presence of congeners in the infracommunities. Therefore, the different water volume of the ventilating current over the arches, the parasite loads and the large two median arches in the bucco-pharyngeal cavity do not explain the distribution of *Eutrianchoratus* spp. on the gill arches of *P. obscura*. Dactylogyrid larvae swim actively and then attach to the skin or gills of susceptible fish (Nack et al., 2010; Tombi et al., 2010); the distribution pattern of at least *E. minutus*, the core species of this xenocommunity, suggests that its oncomiracidia are transported by the ventilating water current, that the filaments of the different gill arches exert an antero-posterior sifting effect on the infecting larvae and that posterior arches and hemibranches are less exposed to oncomiracidia than anterior ones. Our results raise the question of whether there are other models of ventilation of gill filaments in teleosteans than that described by Paling (1968).

The study of parasitism prevalence and abundances in function of hemibranch revealed that *Eutrianchoratus minitus*, *E. imbachi* and *E. chibami* prefer anterior hemibranches. Turgut et al. (2006) showed that *Dactylogyrus* species have a preference for the most ventilated hemibranches. Tombi et al. (2010) showed that *Dactylogyrus insolitus* preferentially binds to the posterior hemibranches of the arc II of *Barbus martorelli* whereas *D. bopeleti*, *D. maillardi* and *D. simplex* have no preference for hemibranches.

The co-occurrence of the different pairs of the three main monogenean species (*E. minitus*, *E. imbachi*, *E. chibami*) at the sectoral and zonal level showed in most cases random colonization. In many others studies, analyzes of interspecific coexistence have shown no interactions (Morand and Simkova, 2005; Tombi et al., 2011). However, some others studies have revealed positive interactions (Silan and Maillard, 1990; Kooskivaara, 1992). Moreover, Rohde (1994) stated that positive interactions between fish ectoparasites are more frequent than negative ones, although Holmes and Price (1986) argued that negative interactions should be frequent. The lack of interspecific competition in this study is also due to the low parasitic intensities inducing niches vacancy within the gill biotope. Indeed, Buchmann (1989), Koskivaara and Valtonen (1991) argue that a multi-species infestation cannot be accompanied by competition as long as there is sufficient space and resources. Price (1980) also considered that as long as there are vacant niches for parasites, interspecific interactions will be rare.

Our finding supports the statement by Koskivaara and Valtonen (1992) that multispecies infection might exist without competition between monogenean species. In our example, there are still enough resources and space in the infracommunities to be exploited in the long term.

Conclusion

The study allowed to identify 5 species of monogenean gill parasites of *P. obscura*. The analysis of their spatial distribution indicated that there was no sex effect, nor size, neither gill side in the distribution of these parasites. In most cases, there was no significant difference in the parasitism of the different gill arches. But there was an antero-posterior model of accumulation of monogeneans on the arches. No evidence of competition between species of *Eutrianchoratus* on the gill tissue was found.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

JN initiated the project. MY collected fish specimens. JN and MY dissected the fish and mounted the parasites. CFBB, FDMM and JN did the statistical analysis. CFBB and JN wrote the article. All the authors corrected and approved the final manuscript.

ACKNOWLEDGEMENTS

The authors thank Dr Antoine PARISELLE of IRD for his technical assistance and Dr Arnold Roger BITJA NYOM of the Institute of Fisheries and Aquatic Sciences of the University of Douala who identified the host species of the studied monogeneans

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