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Spatial distribution of two gill monogenean species from *Sarotherodon melanotheron* (Cichlidae) in man-made Lake Ayamé 2, Côte d'Ivoire

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Abstract

This study describes the spatial distribution of two monogenean species, *Cichlidogyrus halinus* and *C. halli* on the gills of *Sarotherodon melanotheron* from man-made Lake Ayamé 2. A total of 96 *S. melanotheron* were sampled between July 2015 and April 2016. After sampling host, parasites were collected and mounted from each sector of the gill arch. Determination of various monogenean species was carried out by classical methods. Results were analysed with regard to general occurrence of the parasites, mixed infection and single-species infection. A total of 10251 *C. halinus* and 5298 *C. halli* were collected from the fish hosts. A prevalence of 90.63%, abundance of 106.78 and mean infection intensity of 117.83 for *C. halinus* and 89.58%, 55.19, 61.60 for *C. halli* were found. There were no preference observed in the distribution of parasites species over the gill arches between left and right sides of the host. *Cichlidogyrus halinus* preferred gill arch I and the distal-median, distal-dorsal parts of the gill, whereas *C. halli* was found mostly on the gill arches I, II and the distal-median, distal-dorsal parts. In general occurrence of the parasites, mixed infection and single-species infection, the distribution of these species on the gill apparatus has not changed. This indicates the reciprocal tolerance of these parasites.

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Introduction

Monogenean trematodes belong to one of the most species rich classes of the fish parasites. The gills of fishes represent one of the biotope mostly exploited by different fish ectoparasites (Fernando and Hanek, 1976). According to Rohde (1993), gill ectoparasites exhibit a marked preference for certain host microhabitats within the branchial cavity (left or right side, gill arches, external or internal gill filaments). Such restriction of microhabitat is interpreted in many ways: it could be due to variation of the relative volumes of water current passing over the different gills, the available area of arches for attachment, fish traits such an immunity, seasonality or geographic distribution and abiotic environemental conditions such as salinity and temperature (Guitiérrez and Martorelli, 1994).

The knowledge of fish parasites allows understanding of parasites communities structure and the processes involved in the maintenance of this structure. For Combes (1995) core species of parasites explain the spatial structure and mechanisms that determine the coexistence of these organisms on the gill apparatus. Baseline data, collected from infections within natural water systems, serve as reference point for management strategies.

The microhabitat of gill-living monogeneans has been investigated by many authors (El Madhi and Belghyti, 2006; Turgut *et al.*, 2006; Godoy, 2008; Nack *et al.*, 2010; Soylu *et al.*, 2013; Sujana, 2015). In Côte d'Ivoire, there is not information about the microhabitat of monogenean parasites from *Sarotherodon melanotheron*, which is economically and ecologically important as food fish and plays an important role in aquaculture (Legendre *et al.*, 1989 ; Hem and Avit, 1994).

This work presents a study on the spatial distribution of *Cichlidogyrus halinus* and *C. halli* two core species from *Sarotherodon melanotheron* in man-made Lake Ayamé 2 to reveal preference for specific parts of gill apparatus.

Material and methods

Study area

Lake Ayamé 2 is located in southeast Côte d'Ivoire (5°34'-5°37' N and 3°09'-3°10' W) and is the one of hydroelectric dam in the country (Fig. 1). It was built in 1963 on the river Bia and has an average surface of 7 Km² (Da Costa *et al.*, 2000). It rises in Sui (Ghana) and enters Aby lagoon (Côte d'Ivoire).

Sampling and parasitological analyses

A total of 96 specimens of *Sarotherodon melanotheron* were caught monthly between July 2015 and April 2016 by one battery of 14 gill-nets with mesh sizes vary between 8 and 60 mm. Each net measures 30 m long by 1.5 m deep. Gill-nets were set parallel to the bank during high and low water periods. Nets were set overnight (17h-07h) and during the following day (07h-12h).

Once out of the water, the fish were immediately identified following Teugels and Thys van den Audernaerde (2003) keys. Their left and right gill arches were isolated from bucco-pharyngeal cavity by dorsal and ventral sections and then stored in ice (0 °C).

In the laboratory, the gills from each side were dissected. Gills arches from the anterior to the posterior were placed in various Petri dishes numbered from I to IV respectively. Each branchial arch was divided into 6 equal parts, obtaining 24 sectors from four gill arches of one side (Fig. 2).

Parasites were collected from each sector separately and mounted on a slide in a drop of ammonium picrate-glycerine mixture, following the method of Malmberg (1957).

The identification of the parasite species observed were done with a microscope magnification of 400 and 1000X, on the basis of available taxonomic characters as described by Pariselle and Euzet (2009). Prevalence, abundance, intensity and mean intensity were used as defined by Bush *et al.* (1997).

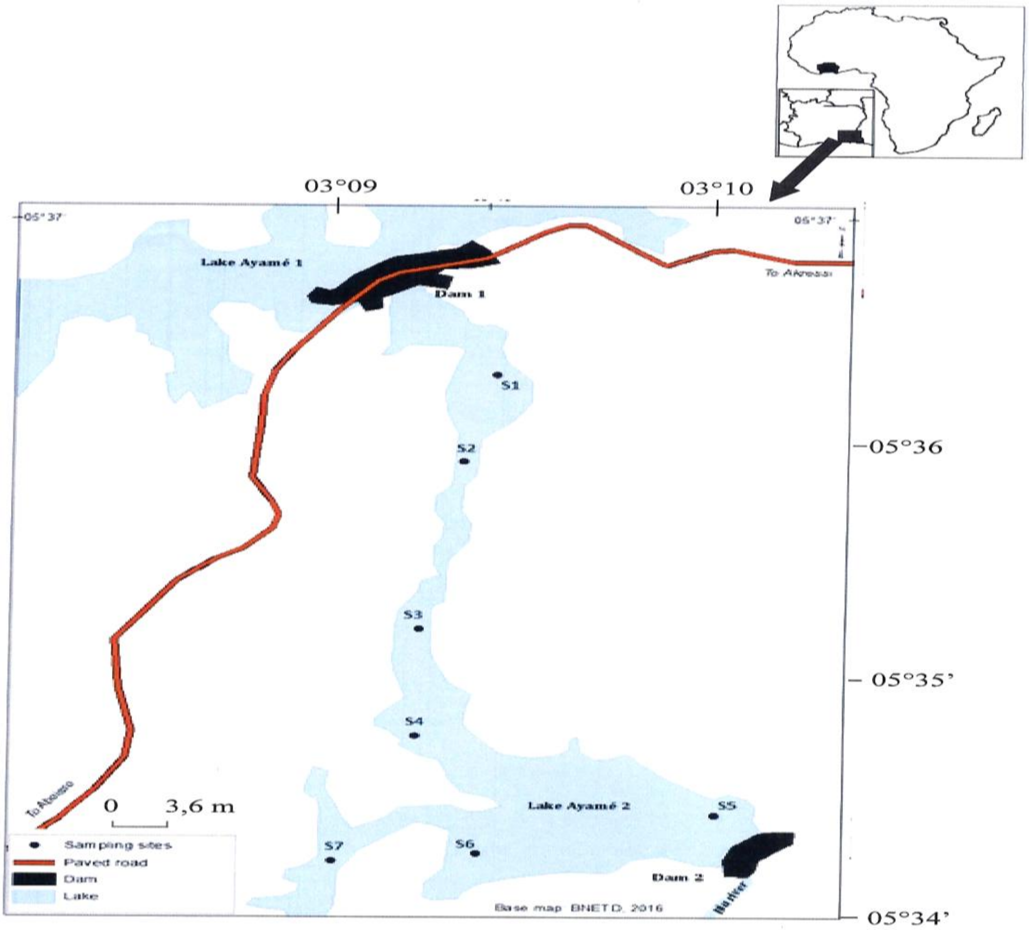

Fig. 1. Geographical location of lake Ayamé 2 (Côte d'Ivoire) and sampling sites.

Statistical analysis

The distribution of monogeneans on particular arches and on parts of the branchial apparatus was analysed by non parametric statistics tests: Mann-Whitney U test and Kruskal-Wallis ANOVA, median test, both in relation to all examined fish and in relation to single and mixed infection. Statistical analysis was performed at the significance level of 5% using STATISTICA 7.1.

Results

A total of 96 *Sarotherodon melanotheron* were examined, 9 of which (9.37%) were not infected at all, 87 (90.63%) were infected by *Cichlidogyrus halinus* and 86 (89.58%) by *C. halli*. A total of 15549 *Cichlidogyrus* spp. were found on the gills of examined fishes; out of these 10251 specimens were *Cichlidogyrus halinus* and 5298 were *C. halli* (Table 1). Abundance was 106.78 for *C. halinus* and 55.19 for *C. halli*. The mean intensity was 117.83 for *C. halinus* and 61.60 for *C. halli* (Table 2).

General occurrence of the parasites

Of 96 examined fish, 87 and 86 were infected with *Cichlidogyrus halinus* and *C. halli* respectively. The distribution of 10251 *C. halinus* and 5298 *C. halli* in general occurrence is shown (Table 1).

The differences were not found to be significant between the number of *C. halinus* ($p = 0.1 > 0.05$) on the left and right sides (Table 2). There were a significantly greater number of this parasite species on the first gill arches than on gill arches II, III and IV ($p = 0.0 < 0.05$). *C. halinus* was more concentrated on dorsal and medial segments on the gills and preferred distal parts of gill arches ($p = 0.0 < 0.05$).

The number of *Cichlidogyrus halli* on the different parts of gill apparatus of *Sarotherodon melanotheron* is shown (Table 2). The data analysis did not show any statistically significant differences in the number of *C. halli* between the right and left side of gill arches of *S. melanotheron* (p= 0.1 > 0.05).

There were a significantly greater number of *C. halli* on the first and second gill arches than on gill arches III and IV (p= 0.0 < 0.05). A greater number of *C. halli* occurred on the dorsal, medial segments and distal parts gill arches (p= 0.0 < 0.05).

Table 1. Spatial distribution of *Cichlidogyrus halinus* (*C. halinus*) and *C. halli* on the gills of *Sarotherodon melanotheron*.

Species	Arch	Side	Sectors of branchial arch						Total
			1	2	3	4	5	6	
C. halinus	I	Right	209	226	386	464	766	562	2613
		Left	205	228	324	459	725	538	2479
	II	Right	163	136	79	407	416	151	1352
		Left	154	154	67	467	432	137	1411
	III	Right	209	32	17	213	164	155	790
		Left	207	41	14	244	161	153	820
	IV	Right	86	27	18	61	88	116	396
		Left	74	32	21	59	92	112	390
C. halli	I	Right	69	133	44	252	322	179	999
		Left	78	145	49	244	331	180	1027
	II	Right	56	63	32	133	293	201	778
		Left	64	62	23	125	290	219	783
	III	Right	147	24	15	197	103	52	538
		Left	154	21	20	210	96	47	548
	IV	Right	115	26	54	58	58	20	331
		Left	108	21	37	62	51	15	294

Distribution of Cichlidogyrus halinus and C. halli on the gills of Sarotherodon melanotheron in mixed-species infections

Of 96 *S. melanotheron* examined, 80 were infected with only *C. halinus* and *C. halli* (Table 3). No significant differences were noticed in the distribution of *C. halinus* and *C. halli* between the right and left sides (p= 0.1 > 0.05).

Arch I was more colonized than the three others by *C. halinus* (p= 0.0 < 0.05). *C. halinus* was more concentrated on dorsal, medial segments and distal part of gill arches (p= 0.0 < 0.05). The monogenean *C. halli* was more abundant on the gill arches I and II than on the others gills arches (p= 0.0 < 0.05) and preferred dorsal, medial segments and distal part (p= 0.0 < 0.05) (Table 3).

Distribution of Cichlidogyrus halinus and C. halli on the gills of Sarotherodon melanotheron in single-species infections

The numbers of *C. halinus* and *C. halli* in single-species infections were also examined (Table 4). Among 96 specimens of *S. melanotheron* sampled 7 were infected with only *C. halinus* and 6 with only *C. halli*. The data presented in the table 4 did not show any statistically significant difference in the number of *C. halinus* and *C. halli* on the right and left side gill arches of *S. melanotheron* (p= 0.7 > 0.05), (p= 0.5 > 0.05) respectively.

Cichlidogyrus halinus was more frequently found on the first arches while the gill arches II, III and IV were the least infected (p= 0.03 < 0.05). This species predominantly occurred on dorsal and medial segments (p= 0.0 < 0.05) and distal part (p= 0.02 < 0.05).

C. halli was more concentrated on arches I and II than on arches III and IV (p= 0.0 < 0.05). Dorsal and medial segments mainly preferred by *C. halli* (p= 0.0 < 0.05) and parasite mostly occupied distal part (p= 0.02 < 0.05).

Table 2. General occurrence of *Cichlidogyrus halinus* (*C. halinus*) and *C. halli* on the gills of *Sarotherodon melanotheron.*

Number of hosts infected	87		86	
Location	*C. halinus*		*C. halli*	
Mean intensity	117.83		61.60	
	Number of parasites	*p value*	Number of parasites	*p value*
Right side	5151	0.1 >0.05	2646	0.1 >0.05
Left side	5100		2652	
Gill arch I	5092	0.0 <0.05	2026	0.0 <0.05
Gill arch II	2763		1561	
Gill arch III	1610		1086	
Gill arch IV	786		625	
Dorsal segment	3681	0.0 <0.05	2072	0.0 <0.05
Medial segment	3720		2039	
Ventral segment	2850		1187	
Proximal part	3109	0.0 <0.05	1560	0.0 <0.05
Distal part	7142		3738	

Table 3. Distribution of *Cichlidogyrus halinus* (*C. halinus*) and *C. halli* on the gills of *Sarotherodon melanotheron* in mixed-species infections.

Number of hosts infected	80		80	
Location	*C. halinus*		*C. halli*	
Mean intensity	114.36		55.2	
	Number of parasites	*p value*	Number of parasites	*p value*
Right side	4575	0.1 >0.05	2207	0.1 > 0.05
Left side	4574		2209	
Gill arch I	4536	0.0 <0.05	1645	0.0 < 0.05
Gill arch II	2476		1308	
Gill arch III	1452		924	
Gill arch IV	685		539	
Dorsal segment	3225	0.0 <0.05	1726	0.002 < 0.05
Medial segment	3274		1701	
Ventral segment	2650		989	
Proximal part	2767	0.0 <0.05	1228	0.0 < 0.05
Distal part	6382		3188	

Discussion

The present study indicated that some parasite have affinity for certain sites of the *Sarotherodon melanotheron* gill system. No significant preferences were found in the distribution of *Cichlidogyrus halinus* and *C. halli* on the gill arches between the left and the right sides of its host.

Similar results were obtained in the Melen fish station in Yaoundé (Cameroon) by Tombi *et al.* (2014) who found that *Cichlidogyrus thurstonae*, *C. halli*, *C. tilapiae* and *Scutogyrus longicornis* colonized the two parts of the gill system of the Nile Tilapia *Oreochromis niloticus* in the same way.

Table 4. Distribution of *Cichlidogyrus halinus* (*C. halinus*) and *C. halli* on the gills of *Sarotherodon melanotheron* in single-species infections.

Number of hosts infected	7		6	
Location	*C. halinus*		*C. halli*	
Mean intensity	157.43		147	
	Number of parasites	*p value*	Number of parasites	*p value*
Right side	576	0.7 >0.05	439	0.5 >0.05
Left side	526		443	
Gill arch I	556	0.03 <0.05	381	0.0 <0.05
Gill arch II	287		253	
Gill arch III	158		162	
Gill arch IV	101		86	
Dorsal segment	456	0.0 <0.05	346	0.0 <0.05
Medial segment	446		338	
Ventral segment	200		198	
Proximal part	342	0.02 <0.05	332	0.02 <0.05
Distal part	760		550	

The same trend was also reported by Blahoua *et al.* (2016) who found no significant difference between the number of monogeneans parasite species (*Cichlidogyrus thurstonae*, *C. halli*, *C. rognoni*, *C. cirratus* and *Scutogyrus longicornis*) on the left and right gill arches of the same host. However, a preference for the right side was recorded by *Dactylogyrus amphibothrium* (Wooten, 1974) and *Microcotyle mugilis* and also preference for the left side was reported by *Dactylogyrus valeti* (Tombi *et al.*, 2016). Hendrix (1990) also found an asymmetrical distribution of of *Bothithrema bothi* (Monogenea) on *Scophtalmus aquosus* (Bothidae). For Dessouter (1992), Bothidae has a flat and dissymmetrical body. Rohde (1993) associated a preference for one side of the host body to body asymmetry of some parasites.

It therefore appears logical that the bilateral symmetry of the body of *S. melanotheron* associated with that of its gill monogeneans allow for an equitable distribution of parasite on both sides of the fish.

In this study, it was shown that *Cichlidogyrus halinus* preferred the first gill arch while *C. halli* was more frequent on the first and second arches. Similarly, in *Barbus meridionalis*, *Paradiplozoon tisae* was found to prefer the arch I (Stavrescu-Bedivanand Aioanei, 2008). Jerônimo *et al.* (2013) also noted that only the Monogenean *Mymarothecium boegeri* and *Anacanthorus penilabiatus* from the hybrid patinga showed the greatest mean intensities on the gill arch I. These observations corroborate with the idea of

Tombi *et al.* (2014) that *Cichlidogyrus halli* showed a preference for arch II. Some authors tried to explain gill selection by parasites.

According to Gutiérrez and Martorelli (1994) and Lo and Morand (2001) the median gill arches II, III are more infested not only because of the large volume of water flowing through them, but also due to the high number of parasite. The median preference arches may also be related to the large colonized surfaces they offer to parasites (Buchmann, 1989 ; Koskivaara and Valtonen, 1991).

Monogeneans also showed a preference for the different part of the gill (Lo and Morand, 2001; Yang *et al.*, 2006; El Madhi and Belghyti, 2006). In *Sarotherodon melanotheron*, *Cichlidogyrus halinus* preferred the distal-median and distal-dorsal halve of the gill arches while *C. halli* distal and dorsal parts filaments. Tombi *et al.* (2010) also found that *Dactylogyrus bopeleti* and *D. insolitus* were more accumulated on the second and third distal halves of gill filaments and especially the distal zone. Other authors have found the same result.

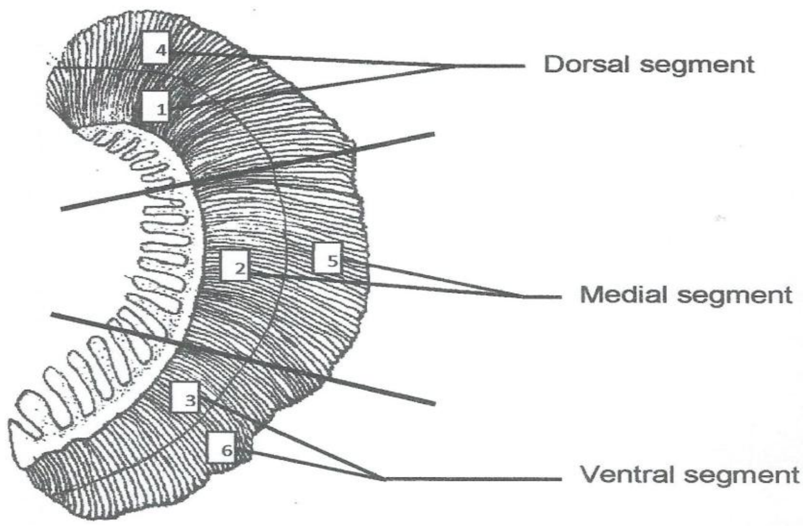

Fig. 2. Division of branchial arch: 1, 4= dorsal segment ; 2,5= medial segment ; 3,6= ventral segment ; 1,2,3= proximal part ; 4,5,6= distal part.

This is the case of Buchmann (1993) and Dzika (1999) with *Pseudodactylogyrus bini* parasite of *Anguilla anguilla*, Bilong Bilong (1995) with species of the genus *Cichlidogyrus* parasites of *Hemichromis fasciatus*. In the litterature, at least two hypothesis are often made to explain the preference of monogeneans for particular site. The size of the gripi (hamuli or hooks or anchor) explains the preferences of site. Bilong Bilong (1995) stated that the monogenean species of genus *Cichlidogyrus* have robust gripi. Thus the presence of relatively robust sclerified haptorial pieces in *Cichlidogyrus halinus* and *C. halli* may enable them to live in the zone of high water movement. According to Paling (1968), more water passes other the distal halves of the filaments than over the proximal. The localization of *Cichlidogyrus halinus* and *C. halli* on the distal part may reflect a preference of these species for a site in which a water flow is maximal.

Intensity of infection of *Cichlidogyrus halinus* was higher when it coexisted with *C. halli* in bispecific infection. The coexistence of these two monogenean species on the same fish does not induce a change in their respective distribution. Intra or inter-specific could not explain the preference of *Cichlidogyrus* *halinus* and *C. halli* on the gill of *Sarotherodon melanotheron*. Indeed, the parasite load of species remained weak and thus most niches remained vacant. According to Koskivaara and Valtonen (1991), a polyparasitism can not conduct to competition as long as there is still space available. Rhode (1979) had showed that many potential niches for ectoparasites of fish were empty and because of this competitive exclusion could not take place. Although Buchmann and Lindenstrom (2002) have added that the exact explanation of site selection by monogenea remains enigmatic. In this study, it appears the intrinsic factors (haptorial phenotypes for *Cichlidogyrus halinus* and *C. halli*) play an important role in the site selection.

Conclusion

The present study contributes to understanding the spatial distribution of *Cichlidogyrus halinus* and *C. halli* on the gill of *Sarotherodon melanotheron* in man-made Lake Ayamé 2. This work constitutes the first extended microhabitat distribution study of the monogenean species on the gill of this fish species in this ecosystem.

It reveals that, *C. halinus* mostly occupied gill arch I and the distal-median, distal-dorsal parts of the gill, whereas *C. halli* was more concentrated on the gill arches I, II and the distal-median, distal-dorsal parts. Thus, the preference for specific parts of *S. melanotheron* gill arches by its monogenean has not changed. This result shows the reciprocal tolerance of these parasites species in the distribution on the gill apparatus. Such information may provide strategies in aquaculture management to reduce potential economic losses of *S. melanotheron* caused by parasitic infection.

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