

Microecology of Monogenean Gill Parasites of *Mormyrus rume* Valenciennes, 1847 from Man-made Lake Ayame I, Côte d'Ivoire: The Role of Intrinsic Factors

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Abstract: The spatial distribution of monogenean species was assessed on the gills of 102 specimens of *Mormyrus rume* from man-made Lake Ayame I between July 2015 and June 2016. Each gill arch was removed and examined to both quantify the number of parasites and their distribution on the gills. Monogenean species of this fish consisted of *Bouixella yaoi*, *B. gorei* and *B. koutouani*. All species were aggregated within the host population. The distribution of these parasites on the gills did not reveal host side preference. However, there were preferences for the specific gill arches. *B. yaoi* had a preference for attachment to second and third gill arches, whereas *B. gorei* tended to settle on the second gill arch. Both parasites, which are their robust sclerified haptorial pieces, accumulate mostly in distal part whereas *B. koutouani* which is weaker, prefer the proximal part of the gill. The low abundance of species recorded had indicated the absence of the intra specific or inter specific competition on the distribution of monogeneans. The volume of the parasite, the phenotype of the haptor, the respiratory water current and probably the reproduction of the parasites are the principal determinants.

Keywords: Monogenea, niche restriction, intrinsic factors, *Mormyrus rume*, man-made lake Ayame I, Côte d'Ivoire.

1. INTRODUCTION

Ectoparasitic monogeneans are essentially fish parasites, most of which infest the skin, gill arches and/or fins. These parasites cause localized hyperplasia, disturbance of osmoregulation and mortality of the host [1-2]. This can also result in secondary infections in the host from viruses, bacteria and fungi [3-4]. These organisms constitute the most ubiquitous and abundant group of helminth parasites in the aquatic environment. In most cases, the monogeneans showed a preference for specific sites of the gill apparatus of their host. These pathogens for example, can be specific for one side of the host, for some arches (or one of their faces), or for some parts of the gill filaments [5]. The microhabitat of gill-living monogeneans has been investigated by many authors [6-12].

Mormyrus rume Valenciennes, 1847 is a commercially important fish distributed along major basins in Sahelo-sudanese in West Africa [13]. This fish is abundant in freshwater in Côte d'Ivoire and contributes significantly to subsistence fishing. Among the riverine populace, it is a delicacy and a source of scarce animal protein and minerals [14-15]. Moreover, its delicious flesh is appreciated by local populations. Despite this economic importance, the gill filaments of this host in the man-made lake Ayame I (Côte d'Ivoire) are parasitized by three monogenean species (*Bouixella yaoi* Blahoua *et al.*, 2009; *B. gorei* Blahoua *et al.*, 2009; *B. koutouani* Blahoua *et al.*, 2009). 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 [16, 11, 15]. The aim of this study is to provide information on some ecological of gill monogenean of *M. rume* by examining the spatial structure of gill of *M. rume* in order to reveal the mechanisms that determine the coexistence of these parasites.

2. MATERIALS AND METHODS

2.1. Study Area

Lake Ayame I is located in southeast Côte d'Ivoire ($5^{\circ} 30' - 6^{\circ} N$; $3^{\circ} - 3^{\circ} 5' W$), and is the oldest hydroelectric dam in the country (Figure 1). The lake was built in 1959 in the river Bia. The reservoir has a mean depth of 10 m and a mean area of 135 km² [17]. It rises in Sui (Ghana) and enters Aby lagoon (Côte d'Ivoire). The lake Ayame I level is subject to fluctuations depending on local rainfall and evaporation.

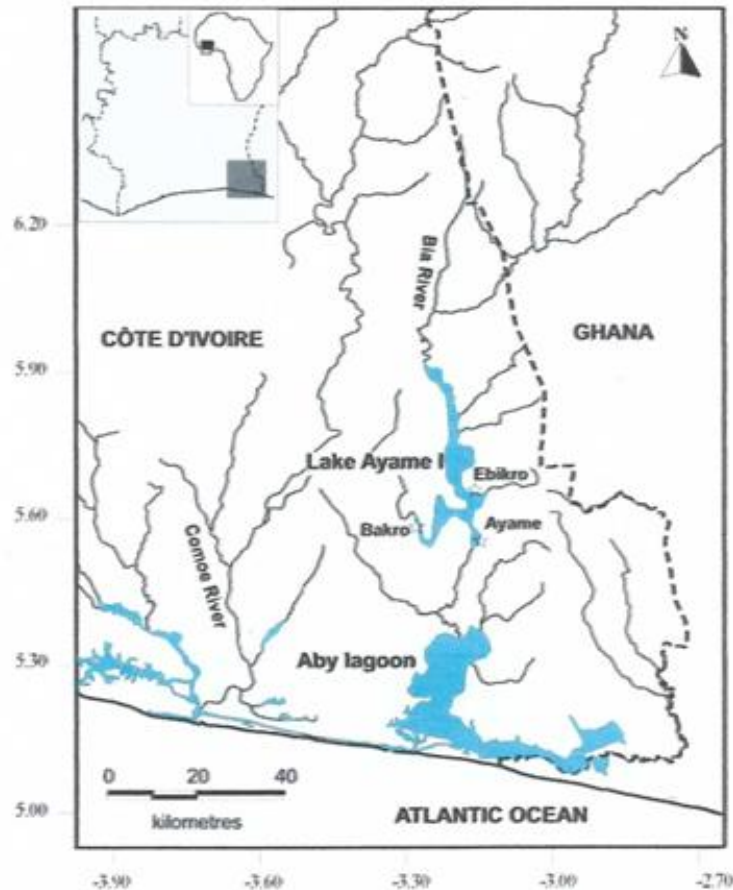


Figure1. Geographical situation of lake Ayame I (Côte d'Ivoire) and sampling sites (☆)

2.2. Fish Sampling

Sampling was carried out at the three landings sites between July 2015 and June 2016. One hundred and two specimens of *Mormyrus rume* were sampled monthly using gillnets. Once caught, the fishes were immediately identified according to the keys given by [18]. After being identified fish, the operculum was removed to expose the gills, which were carefully removed fresh, separated into left and right, and stored in ice (0°C).

2.3. Spatial Distribution on Fish Gills

Gills from the left and right sides of the fish were dissected. The gill arches were numbered I to IV from anterior to posterior. Each arch was divided into three gill segments: dorsal, medial and ventral; two gill areas: proximal and distal (Figure 2). Each gill segment was individually placed in a separate Petri dish with several drops of filtered water and was monitored using a binocular microscope (OLYMPUS SZ 60). Monogeneans were collected and mounted on a slide in a drop of ammonium picrate-glycerine [19]. All species were identified with a microscope magnification of 400 and 1000X, on the basis of available taxonomic characters as described by [20]. Monogeneans identified were counted from each the sectors separately. The position of each individual species was recorded. The dispersion index (S^2/X) was used to examine the pattern of aggregation of the species of ectoparasites [21].

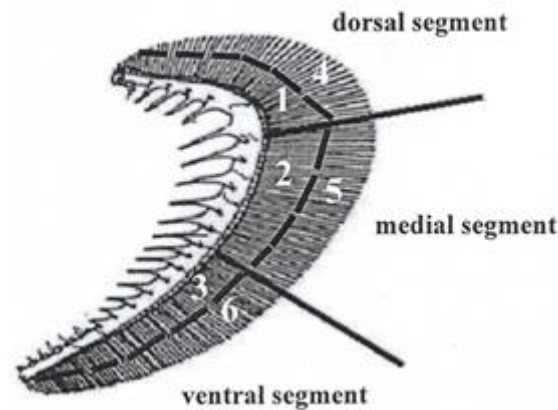


Figure2. Numbering of branchial arch, 1=Proximal-dorsal, 2=Proximal-medial, 3=Proximal-ventral, 4=Distal-dorsal, 5=Distal-medial, 6=Distal-ventral

2.4. Statistical Analysis

Prevalence and mean intensity were determined according to [22]. The distribution of monogenean species was analyzed by nonparametric statistics tests, Kruskal Wallis ANOVA test, and followed by Mann-Whitney U tests to determine the parasite population differences between the gill arches and between the segments. The Kruskal Wallis (K) test was to compare the intensities of more than two samples. The Mann-Whitney (U) test was used to compare the intensity of infection of two different samples. The Chi square (χ^2) test was used to compare two or more proportions. Differences of $p < 0.05$ were considered significant. Computations were performed using Statistical Package for Social Science (SPSS) 16.0.

3. RESULTS

A total of 102 *Mormyrus rume* was examined for the presence of monogenean species. Of the hosts infected, 82 (80.39%) harbored *Bouixella yaoi*, 79 (77.45%) harbored *B. gorei* and 24 (23.53%) harbored *B. koutouani* (Table 1). The 3064 collected monogeneans comprised 1612 *B. yaoi*, 1392 *B. gorei* and 60 *B. koutouani*. Their low mean intensities of infection were respectively: 19.65 ± 0.1 , 17.62 ± 1.2 and 2.5 ± 0.4 . The values of variance were 642.75, 433.4 and 10.75. These three species had the typical aggregated pattern of distribution ($S^2 > IM$).

Table1. Prevalence (%) and mean intensity (MI) \pm SE of *Bouixella* species of *Mormyrus rume*

Parasite species	H	N	N	P(%)	MI \pm SE
<i>Bouixella yaoi</i>	102	82	1612	80.39	19.66 ± 0.1
<i>Bouixella gorei</i>	102	79	1392	77.45	17.62 ± 1.2
<i>Bouixella koutouani</i>	102	24	60	23.53	2.50 ± 0.4

H : number of examined fishes ; N : number of infected fishes ; n : number of parasites ; SE : standard error

3.1. Distribution of Monogenean Species at the Host Side Level

The distribution of monogenean species on the right and left gill arches of *Mormyrus rume* was analyzed (Table 2).

The rate of occupation and mean intensity of *Bouixella yaoi*, *B. gorei* and *B. koutouani* were not statistically different between the right and left side of the host ($p > 0.05$, respectively $\chi^2 = 0.12$, 0.11 and 0.03 for the rate of occupation and U= 4.1, 5.6 and 3.4 for mean intensities).

Table2. Prevalence (%) and mean intensity (MI) \pm SE of *Bouixella* species on right and left sides of the gills of *Mormyrus rume*

Parasite species	<i>Bouixella yaoi</i>		<i>Bouixella gorei</i>		<i>Bouixella koutouani</i>	
P (%)	80.39	78.43	77.45	75.49	21.56	23.52
MI \pm SE	9.89 ± 0.2	10.01 ± 0.18	8.71 ± 0.1	9.14 ± 0.09	1.4 ± 0.01	1.21 ± 0.03

SE : standard error

3.2. Distribution of Monogenean Species at the Arches Level

The pattern of gill occupation of the monogenean species of *M. rume* was shown (Table 3).

Bouixella yaoi mostly occurred on the second and third gill arches and its parasitic load decreased significantly in the anteroposterior direction ($K= 17.03$, $df=3$, $p < 0.05$).

B. gorei was more abundant on the second and first gill arches compared to the other two ($K= 21.04$, $df=3$, $p < 0.05$). Parasitic load decreased significantly in the anteroposterior direction.

B. koutouani mostly infected the fourth gill arch. Parasitic load of this species decreased significantly in the posteroanterior direction ($K= 34.04$, $df=3$, $p < 0.05$).

Table3. Prevalence (%) and mean intensity (MI) ± SE of *Bouixella* species on gill arches

Parasite species						
	<i>Bouixella yaoi</i>		<i>Bouixella gorei</i>		<i>Bouixella koutouani</i>	
Gill arches	P (%)	MI ± SE	P (%)	MI ± SE	P (%)	MI ± SE
I	69.51	3.57 ± 0.01	97.47	7.29 ± 0.3	25	1.16 ± 1.1
II	95.12	8.51 ± 0.04	98.73	7.66 ± 0.02	25	1.5 ± 0.2
III	98.78	8.31 ± 1.3	74.68	3.32 ± 0.01	20.83	1.4 ± 1.01
IV	40.24	1.64 ± 0.5	30.38	1.5 ± 0.2	50	3.08 ± 0.02

SE : standard error

3.3. Distribution of Monogenean Species at the Filamentous Zones Level

The occupation model of the filamentous zone was analyzed (Tables 4 and 5). *Bouixella yaoi* showed more affinity for the medial and ventral segments ($K= 18.02$, $df=3$, $p < 0.05$) and the distal part of the gill arch ($U= 9.42$, $df=1$, $p < 0.05$).

B. gorei preferred the medial and ventral segments of the gill arch ($K= 10.05$, $df=3$, $p < 0.05$). This species mostly occurred on the distal part ($U= 6.12$, $df=1$, $p < 0.05$).

B. koutouani was more abundant on the dorsal segment ($K= 4.01$, $df=3$, $p < 0.05$) and the proximal part of the gill ($U= 2.10$, $df=1$, $p < 0.05$).

Table4. Prevalence (%) and mean intensity (MI) ± SE of *Bouixella* species on gill arch segments

Parasite species						
	<i>Bouixella yaoi</i>		<i>Bouixella gorei</i>		<i>Bouixella koutouani</i>	
Gill segments	P (%)	MI ± SE	P (%)	MI ± SE	P (%)	MI ± SE
Dorsal	78.05	3.29 ± 0.01	81.01	2.86 ± 0.4	100	1.88 ± 0.03
Medial	97.56	8.73 ± 0.06	100	7.8 ± 0.02	29.16	1.14 ± 0.1
Ventral	100	8.57 ± 0.1	97.46	7.7 ± 0.05	29.16	1 ± 03

SE : standard error

Table5. Prevalence (%) and mean intensity (MI) ± SE of *Bouixella* species on gill arch parts

Parasite species						
	<i>Bouixella yaoi</i>		<i>Bouixella gorei</i>		<i>Bouixella koutouani</i>	
Gill zone	P (%)	MI ± SE	P (%)	MI ± SE	P (%)	MI ± SE
Proximal part	70.73	5.06 ± 0.3	41	6.59 ± 0.08	95.83	2.1 ± 0.01
Distal part	97.56	16.47 ± 1.7	100	14.95 ± 1.9	41.66	1.2 ± 0.03

SE : standard error

3.4. Mixed Species Infection

Mixed infections of *Momyrus rume* were examined with *B. yaoi*-*B. gorei* and *B. yaoi*- *B. koutouani* combinations (Table 6).

Table 6. Distribution of *Bouixella* species on mixed species infections

	B. yaoi		B. gorei		B. yaoi		B. Koutouani	
Number of infected host	52		52		14		14	
Mean intensity	23.11		24.06		16		2.64	
	P (%)	IM ± SE	P (%)	IM ± SE	P (%)	IM ± SE	P (%)	IM ± SE
Right side	94.23	11.61 ± 0.1	76.2	12.09 ± 0.3	95	7.71 ± 0.2	91	1.54 ± 0.04
Left side	96.3	11.5 ± 0.3	79	11.96 ± 0.1	98	8.28 ± 0.1	93.6	1.3 ± 0.2
Gill arch I	68.42	2.94 ± 0.02	92.3	9.63 ± 0.02	66.2	1.71 ± 0.01	23.1	0.4 ± 0.01
Gill arch II	96	9.25 ± 0.01	94.5	9.54 ± 1	92	6.7 ± 0.03	21.7	0.5 ± 0.01
Gill arch III	98.8	9.35 ± 0.5	72.8	3.13 ± 1.1	97.7	7 ± 1.2	20.2	0.46 ± 0.03
Gill arch IV	39.2	1.58 ± 0.02	24.62	1.75 ± 0.01	29	0.6 ± 0.2	88.1	1.4 ± 0.1
Dorsal segment	76.2	2.1 ± 0.6	79.74	2.63 ± 0.3	64.6	1.64 ± 0.1	91.3	1.84 ± 0.3
Medial segment	98.4	10.52 ± 1.3	98.9	10.61 ± 0.1	96.8	7.36 ± 0.01	20.8	0.53 ± 0.01
Ventral segment	100	10.63 ± 1.02	94.8	10.79 ± 2.2	99.6	7 ± 1.3	20.7	0.46 ± 0.04
Proximal part	73.1	43.1 ± 0.3	38	5.08 ± 0.2	71.3	3 ± 0.03	98.8	2.15 ± 0.3
Distal part	95.7	18.81 ± 2.1	100	18.98 ± 1.7	99.4	13 ± 2.2	34.9	0.7 ± 0.01

Of the 102 examined fish, 52 specimens were simultaneously only infected by *B. yaoi*-*B. gorei* (prevalence = 50.98%). In these fishes, 1202 *B. yaoi* and 1251 *B. gorei* were recorded. *Bouixella yaoi* predominantly occurred on the second and third gill arches compared with the fourth one ($K= 14.5$, $df=3$, $p < 0.05$). This species was more frequently on the medial and ventral segments ($K= 8.23$, $df=2$, $p < 0.05$) and the distal part of the gill ($U= 5.40$, $df=1$, $p < 0.05$). Most individuals of *B. gorei* preferred the first and second gill arches ($K= 10.2$, $df=3$, $p < 0.05$). This monogenean was more abundant on the medial and ventral segment ($K= 6.1$, $df=3$, $p < 0.05$) and the distal part ($U= 3.42$, $df=1$, $p < 0.05$).

Fourteen specimens were only coinfecting by *B. yaoi*-*B. koutouani* (prevalence = 13.72%). In these fishes, 224 *B. yaoi* and 37 *B. koutouani* were collected in these infections. *Bouixella yaoi* was more frequently on the second and third gill arches ($K= 29.71$, $df=3$, $p < 0.05$), on the medial and ventral segments ($K= 178.23$, $df=2$, $p < 0.05$.) and on the distal part ($U= 7.45$, $df=1$, $p < 0.05$) whereas *B. koutouani* preferred the fourth gill arch ($K= 15.34$, $df=3$, $p < 0.05$), the dorsal segment ($K= 5.23$, $df=3$, $p < 0.05$) and the proximal part ($U= 2.75$, $df=1$, $p < 0.05$).

3.5. Single Species Infection

Single species infection of *Mormyrus rume* were analyzed with *Bouixella yaoi*, *B. gorei* and *B. koutouani* (Table 7).

Of the 102 fish examined, 16 hosts (prevalence= 16.69%) were only infected with 186 *B. yaoi*. This species predominantly occurred on the second and third gill arches ($K= 7.4$, $df=3$, $p < 0.05$). It preferred medial and ventral segments ($K= 9.22$, $df=2$, $p < 0.05$) and the distal part of the gill ($U= 3.9$, $df=1$, $p < 0.05$).

Eight hosts (prevalence = 8.43%) were only parasitized with 126 *B. gorei*. This parasite species preferred the first and second gill arches ($K= 4.8$, $df=3$, $p < 0.05$), medial and ventral segments ($K= 7.28$, $df=2$, $p < 0.05$) and the distal part ($U= 1.67$, $df=1$, $p < 0.05$).

Eight hosts specimens (prevalence = 8.43%) were only harbored 19 *B. koutouani*. The fourth gill arch was more colonized than the other three ($K= 2.2$, $df=3$, $p < 0.05$). It mostly occupied dorsal segment ($K=4.71$, $df=2$, $p < 0.05$) and the proximal part of the gill ($U= 1.33$, $df=1$, $p < 0.05$).

4. DISCUSSION

This study has underlined a simultaneous colonization of three monogenean species parasitizing the gills of *Mormyrus rume* from man-made lake Ayame I. In Côte d'Ivoire, fish polyparasitism by monogeneans is quite well documented [20, 16, [23], 11, 15]. This multi-specific parasitism of this fish species could be explained by the permanent presence of vacant niches on its gill biotope. The coexistence of congeneric species in the gill system of *M. rume* allows the exclusion of interspecific

competition among the factors involved in the structuring of this component community. Indeed, [24] argued that a competition does not permit similar species to coexist. Also, the positive interactions are more frequent between fish ectoparasites of the same host than negative interactions [25]. According to [26], the coexistence is due to the niche heterogeneity, unpredictable recruitment or the aggregated utilization of fragment resources.

Monogenean studied presented an aggregate distribution. In most cases, the parasites are almost universally aggregated between their hosts [27]. This typical distribution pattern in fish parasites could be explained by heterogeneity of the host-parasite relationship [28]. Indeed, the probability for the parasite to meet its host and its chances of surviving in the latter, may vary from one host to another.

The right and left body sides of *M. rume* were similarly infected by monogenean species *Bouixella yaoi*, *B. gorei* and *B. koutouani*. The symmetric distribution of monogenean gill parasites is a well-documented phenomenon [10, 16, 15, 12]. 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 [29, 16].

The mean intensity and prevalence of the core (*Bouixella yaoi* and *B. gorei*) species decreased antero-posteriorly from first arch to fourth arch, while for the rare (*B. koutouani*) species, the parasite load decreased postero-anteriorly. Concerning the variation of the parasite load of the core species, our results coincide with those of [30] for monogenean *Mymarothecium boegeri* and *Anacanthorus penilabiatus* from the hybrid patinga on the first three gill arches when compared with fourth gill arch. Similarly, [31] had showed that, on the one hand, the second and third gill arches of *Lutjanus guttatus* were more infected by *Haliotrematoides plectridium* and, the other hand, the first and second gill arches were preferred by *Euryhaliotrematoides perezponcei*. In various other cases, monogenean parasites prefer the two median arches (the second and third one) [32]. This preference is attributed to not only because of the large volume of water flowing through the median arches, but also due to the high number of parasite [33-34]. Differences in colonization surface of gill arches also could influence this preference. In fact, according to [35], the median arches offer large colonization surface to parasites increasing thus the possibility of their invasion by oncomiracidiums. Spatial distribution is thus not due to active choice of attachment site, but rather a result of respiratory current, host fish behavior and habitat use [36]. Concerning the variation of the parasite load of the rare species, our results coincide with those of [37] who showed that *Quadriacanthus* sp. and *Birgiellus kellensis*, gill monogeneans of *Clarias camerunensis*, prefer the fourth gill arch rather the first one. The mode of colonization of Monopisthocotylea larvae could justify this preference [38-39]. Indeed, the infesting larvae settle first on the skin and then migrate towards the gills. Thus, these organisms reach the fourth gill arch and the other three progressively. We also think that the ventilation current of gill filaments only contributes to increase the heterogeneity of sites fixation of parasites. The model exploitation of *B. koutouani* is posterior-anteriorly therefore contrast with those of [40] with *Dactylogyrus nanus* et *D. micracanthus* in *Rutilus rutilus*.

In *Mormyrus rume*, *Bouixella yaoi* and *B. gorei* mostly parasitized both the distal-medial and distal-ventral segments of the gill filament, whereas *B. koutouani* was attached essentially to proximal-dorsal segment. Many researchers agreed upon this observation in Cichlid species. [11] found that in *Sarotherodon melanotheron*, *Cichlidogyrus halinus* preferred the distal-medial and distal-dorsal halve of the gill arches while *C. halli* distal-dorsal segment. In *Tilapia zillii*, distal-medial and distal-ventral segments were more colonized by *Cichlidogyrus ergensis*, while distal-dorsal and distal-medial segments were preferred by *C. cubitus*, *C. anthemocolpos*, *C. digitatus* and *C. arthracanthus* [15]. The size of the sclerified haptorial pieces explains the preferences of site. In fact, the presence of relatively robust haptorial pieces in *B. yaoi* and *B. gorei* [20] enables them to live in the zones of high water movement, while *B. koutouani* with weaker sclerified haptorial pieces [20] are protected from this high force of the ventilation.

This work has indicated that occur the segregation of monogenean gill parasites of *M. rume*. The most abundant monogenean species *B. yaoi* and *B. gorei* preferred both the distal-medial and distal-ventral segment of the gill. This spatial niche restriction of *Cichlidogyrus* may facilitate locating mate. The parasite load of the infracommunities remains weak and thus most niches remain vacant. The

aggregation of individuals of each parasite species on specific zone and the low parasitic intensities within the gill biotope suggest the absence of interspecific competition (even intraspecific) among these parasites. Similarly, [34] stated since vacant niches are available, interspecific competition is unimportant for freshwater and marine gill parasites of fishes. Indeed, [41], [35] argued that a multi-species infestation cannot be accompanied by competition as long as there is sufficient space and resources.

5. CONCLUSION

The study allowed to identify 3 species of monogenean gill parasites of *Mormyrus rume*. The analysis of their spatial distribution indicated that there was no significant difference in the parasitism of the different gill arches. However, there was an anteroposterior model of accumulation for the majority of the representative of the studied component monogeneans on the arches. No evidence of competition between species of *Bouixella* on the gill arch was found.

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