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Condition factor of a natural strain of Hybrid (*Coptodon zillii* x *C. guineensis*) infested by gill Monogenean parasites in sector IV of the Ebrié lagoon (Côte d'Ivoire)

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Abstract

The Hybrid fish is a species highly prized by fishermen and local populations in sector IV of the Ebrié lagoon.Due to anthropogenic activities that modify the water quality of the lagoon, this fish may be threatened by pathogenic organisms such as gill parasitic Monogeneans that can affect its condition factor. This study aimed to evaluate the impact of parasites on the body weight of hybrid fish in sector IV of the Ebrié lagoon. The fish were examined from January 2022 to December 2022. Sampled fish were identified and examined for parasites according to standard procedures. Their lengths and weights were measured to determine their condition factors. Six species were identified. Seasonal changes in the rates of infection for all the monogenean species were found with the highest values of mean intensity were observed in the rainy seasons and the lowest one in the long dry season. It also showed that the sex and host size influenced the parasites burden. The study found that all fish examined had a condition factor of less than 1 (K <1). However, there was a significant difference between the condition factors of infested and uninfested fish. Infested fish were skinny than uninfested fish. They were in poor physiological condition.

Keywords: Fish, parasites, Condition factor, Ebrié Lagoon.

Introduction

Fish is a very important food resource in Africa. For low-income populations, it is often the only source of protein accessible to all. They are hosts to many parasites, notably Monogeneans. These parasites are mostly ectoparasites whose life cycle does not require an intermediate host[1]. They frequently infest various organs, namely the gills, skin, fins, rectal cavity, nostrils and stomach[2]. Monogeneans cause diseases that affect the health and reproduction of fish, making them easy prey for predators. Parasitic infections in fish cause production and economic losses through direct fish mortality, reduced growth, fecundity and endurance of fish, increased susceptibility of fish to disease and predation[3]. Some parasitic infections manifest themselves through symptoms that depend on the external treatment of the fish. For others, the health status of the fish is determined by the analysis of condition factors[4]. Condition factor is a measure of the energy, nutritional status, and viability of a host. It is used to characterize the physiological state and body weight of fish during their life cycle[5]. Weight gain corresponds to better body weight and good physiological condition in fish.

In the natural environment, several cases of hybridization have been reported in both freshwater and lagoon waters[6,7]. The Ebrié lagoon is not spared from these cases of hybridization. Indeed, a case of hybridization between *Coptodon guineensis* and *C. zillii* has been observed. These fish are abundant in most lagoons and freshwaters in Côte d'Ivoire[6-8]. They constitute a significant proportion of the total catch, which makes the fish in the fishery. Despite this importance, the Hybrid faces infections by parasitic Monogeneans in the Ebrié lagoon which could negatively impact its body weight and physiological condition. The objective of this work is to evaluate the effect of parasitism on the plumpness of hybrid fish in sector IV of the Ebrié lagoon.

Material and Methods

Study area: The fish studied were captured in the sector IV of the Ebrié lagoon (5°18'N-5°18'49''N; 4°19'W-4°23'08''W) (Figure-1) in the department of Dabou. Seasonal variations in salinity in this sector are considerable and a little less marked, between approximately 15% and 2%. The study areas benefit from a transitional equatorial climate with four seasons[9]: a long rainy season extends from April to July, a short dry season

extends from August to September, a short rainy season lasts from October to November and a long dry season from December to March. The average annual rainfall is between 1400 and 1600 mm[10]. Floods occur at two times of the year, from June-July and from October-November. Low water levels occur from December to March and from August to September. These are as vegetation were dominated by dense rainforest[10]. The plant associations observed in sector IV of the Ebrié lagoon consist of endangered fixed swimming hydrophytes (*Nymphaea lotus*) and free-swimming hydrophytes (*Pistia stratiotes*, *Salvinia molesta*, *Eichhornia crassipes*). Agricultural activities that develop along this body of water include cassava, plantain, and rubber plantations. Most of these plantations use large quantities of fertilizers and phytosanitary products.

Fish collection and identification: One hundred and fifty seven (157) samples of fish identified as Hybrid were collected monthly from January 2022 to December 2022. The fish samples were collected with gillnets. They were identified according to the key of Dunz and Schliewen[11]. Then, the morphometric measurements including the standard lengths (Horizontal distance from the anterior end of the snout to the base of the caudal fin) and total lengths (Horizontal distance from the anterior end of the snout to the posterior end of the caudal fin) all in millimeters of each specimen were made. The fish were then weighed in grams using an electronic scale. The fish sex was determined by observing the gonads. Male fish have filiform gonads that are often very thin and milky in color when they are mature. However, females have oval gonads[12]. The size classes were formed with an amplitude of 30cm: small size (14-16.9cm), medium size (17-19.9 to 20-22.9cm) and large size (23-25.9cm).

Condition factor (K): The Fulton's Condition Factor (K) assumes that the weight of the fish is proportional to the cube of the length and was used to assess the general health of the fishes, on individual and population level. In all individuals' total length, standard length and body mass were measured. The allometric equation where the b exponent is a constant was used to compare the health index of the different category of fishes.

Thus, Fulton's condition factor (K) was calculated using the formula[13]:
$K = W*100/ L^b$
Where W = weight of fish (g), L = standard length of the fish (cm), b= coefficient of allometry considered equal to 3.

The Fulton's condition factor was multiplied with 100 to get it close to 1, and the number 1 indicated a normal condition of the fish, greater 1 indicated fat fish and less than 1 indicated skinny fish. This morphometric index assumes that the heavier fish for a given length the better condition.

Parasite Collection: After catching the fish, the gills were immediately removed by dorsal and ventral section, then referenced according to the fish and stored individually in aluminum foil packets in the cold (ice in the field, -20°C freezer in the laboratory) until examination. In the laboratory, after thawing the gills in the open air, the gill filaments were washed using a squeeze bottle. The rinsing water collected in a Petri dish as well as the gill filaments were examined under a binocular microscope (magnification x 60). The observed monogeneans were detached using 00 entomology needles mounted on a watchmaker's mandrel and then mounted between slide and cover slip in a micro drop of the ammonium picrate glycerin mixture[14]. The determination of the species of gill Monogenean parasites was done under a microscope (magnification x 100) using the identification key of Pariselle & Euzet[15].

Parasitic Indices: To assess parasitism, the indices of prevalence (P%) and mean intensity (MI) were calculated according to Bush *et al*.[16].

Prevalence (P%) is the percentage ratio between the number of hosts infested (N) by a given parasite species and the number of fish examined (H).
P = N/H x 100
The adopted classification of parasite species based on prevalence is that of Pariselle, A., & Euzet, L.[15].
Dominant species: (prevalence > 50%)
Satellite species: (10 ≤ prevalence ≤ 50%)
Rare species: (prevalence < 10%)

Mean parasite intensity (IM) is the ratio of the total number of individuals of a parasite species (n) in a sample of hosts to the number of infested hosts (N) in the sample.
IM = n/N

Statistical analysis: The Chi-square (X^2) test was used to compare two or more proportions (prevalence). The Kruskal Wallis (K) and Mann Whitney (U) tests were respectively used to compare several or two intensity of infection. Differences of $p < 0.05$ were considered significant. All statistical analyses were performed using by Excel and STATISTICA 7.1 software.

Results and Discussion

Gill Monogeneans species composition: Six parasite species have been identified on the Hybrid (*Coptodon zillii x C. guineensis*) gills (Table-1). These are *Cichlidogyrus cubitus*, *C. ergensis*, *C. vexus*, *C. anthemocolpos*, *C. dossoui* and *C. digitatus*. In this environment, the parasites *C. cubitus* (96.82%), *C. ergensis* (94.27%) and *C. vexus* (71.34%) were the dominant species on the gills of the Hybrid with prevalences greater than 50%. Monogenean species *Cichlidogyrus anthemocolpos*, *C. dossoui* and *C. digitatus* whose prevalences values were comprised between 10 % and 50% are the secondary species. These respective values obtained were 49.68, 42.04 and 32.48%.

Hybrid (*Coptodon zillii* x *C. guineensis*) parasitism and condition factor (K) according to seasons: Concerning the

prevalence, the highest values of *Cichlidogyrus cubitus* (92.6%), *C. ergensis* (83.4%), *C. vexus* (86.2%), *C. anthemocolpos* (48.16%), *C. dossoui* (49.54%) and *C. digitatus* (33.6%) were recorded in the rainy season (Table-2). The Chi-square test carried out on the parasite prevalences during the seasons revealed significant differences (Chi-square test (X^2); $p < 0.05$).The evolution of the seasonal variation of the mean intensity follows that of the prevalence. The maximum values were noted in the rainy season. These intensities were 12.8±0.4 for *C. cubitus*, 10.6±1 for *C. ergensis*, 11.1±0.5 for *C. vexus*, 7.2±2 for *C. anthemocolpos*, 6.9±0.1 for *C. dossoui* and 5.6±1 for *C. digitatus*. The Mann-Whitney test applied to the intensities indicated that fish were more parasitized during the rainy season ($p < 0.05$).

Table-3 presents the average values of condition factors (K) of infested and uninfested fish according to seasons. The analysis highlighted that the condition factor values of uninfested fish were 0.87±0.14 in the rainy season and 0.64±0.01 in the dry season. For infested hosts, the values were 0.52±0.1 and 0.48±0.02 in the rainy season, and dry season, respectively. The Mann Whitney U test showed a significant difference in condition factors between infested and uninfested fish in both seasons ($p<0.05$). Infested fish were generally skinny than uninfested ones. However, within parasitized fish, the observed difference between the values was not significant ($p > 0.05$).

Hybrid (*Coptodon zillii* x *C. guineensis*) parasitism and Condition Factor (K) according to the sex: The analysis included a total of 157 Hybrid (*Coptodon zillii* x *C. guineensis*) specimens, including 77 males and 80 females (Table-4). Male fish were more infested by the parasites *Cichlidogyrus cubitus* and *C. ergensis* with respective prevalences of 97.22% and 82.91% and corresponding mean intensities values of 13.2±2 and 11.9±1 (Chi-square test (X^2) = 17.2, $p=0.001< 0.05$; Mann-Whitney U test, $p = 0.001< 0.05$). For both sexes combined, the mean prevalences and intensities were 78.2% 11.6±0.7 with the parasite *C. cubitus* and 67.9% and 10.8±0.4 in *C. ergensis*. Gill monogenean parasites *Cichlidogyrus vexus*, *C. anthemocolpos* and *C. dossoui*more infest females more with respective prevalences of 78.7, 45.2 and 47.3%. The corresponding mean infestation intensities were 12.6±1, 9.6±0.4 and 9.52±0.1. The Chi-square test performed on the prevalences and the Mann Whitney test applied to the intensities highlighted significant differences in the infestation of male and female fish by these parasites (X^2 = 4.61, 5.48, 5.42; $p = 0.021$, $0.01 < 0.05$ and 0.001; $p=0.01$, 0.02 and $0.002 <0.05$). The mean prevalences and intensities of these parasites evolved in the same direction when the sexes were combined. The Monogenean *C. digitatus* parasitized both male and female fish with prevalences of 28.63% for male hosts and 39.1% for females. The mean intensities assigned to these prevalences were 4.9±0.5 and 5.4±0.3. No significant difference was observed for the prevalences (Chi-square test $X^2 = 0.43$; $p = 0.5 >0.05$; Mann Whitney U test, $p = 0.12 >0.05$). The parasite prevalence for the sexes combined was 32.43% and the mean intensity was 4.1±0.2.

This study revealed that the condition factor (K) values of unparasitized fish of all sexes were less than 1 ($K<1$) (Table-5). For infested males and females the values were 0.51±1.6 and 0.32±0.02, respectively. The Mann Whitney U test established a significant difference in condition factors between infested and uninfested fish ($p < 0.05$).Furthermore, female fish were skinny than male fish (Mann Whitney U test, $p < 0.05$). The combined sexes had condition factors that varied from 0.89±0.13 for unparasitized fish to 0.38±0.2 for parasitized fish.

Hybrid (*Coptodon zillii* x *C. guineensis*) parasitism and Condition factor as a function to host size: The parasite prevalence in relation to standard length indicated that the highest parasite infection was in the size range of 23-25.9 cm with 96.23% infected fish and a mean intensity of 12.63±1 followed by the size range of 20-22.9cm with a prevalence (96.23%) and a mean intensity of 8.6±0.2 (Table-6). A significant difference (Chi-square tests; $p < 0.05$) was observed in the variation of prevalences. The application of Kruskal-Wallis (K) tests followed by post-hoc tests carried out on the intensities showed that the infestation of the Hybrid by parasites is higher in larger fish ($p < 0.05$).

Regarding the body weight of unparasitized fish, all size classes had mean condition factor (K) values less than 1 (Table-7). In parasitized fish these values increased from the smallest size class (14-16.9cm) and reached the maximum at the largest size class (23-25.9cm). These respective values were 0.31±0.02 and 0.48±0.02. The Mann Whitney U test revealed a significant difference in condition factors between infested and uninfested fish in each fish size class ($p < 0.05$).

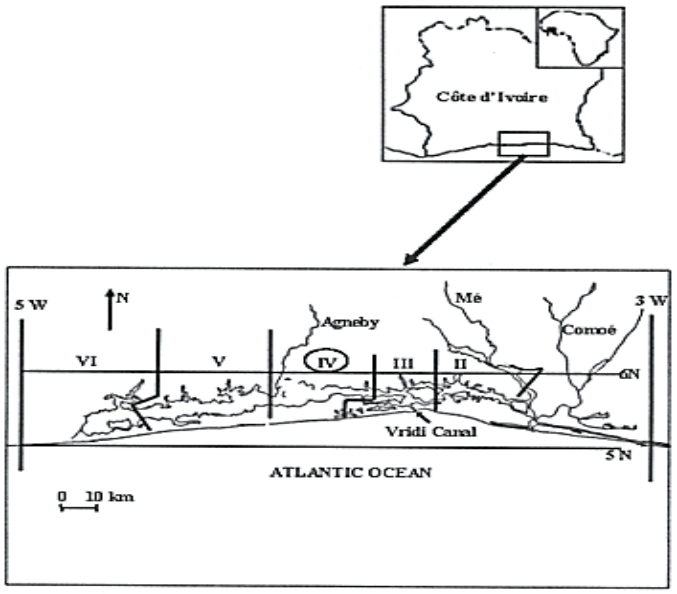

Figure-1: A map of the Ebrie lagoon showing the study area.

Table-1: Prevalence and mean intensity of gill Monogenean species collected in the Hybrid (Coptodon zillii x C. guineensis) in sector IV of the Ebrié lagoon.

Monogenean species	Examined host	Infected host	% Prevalence	Mean Intensity ± Standard Error
Cichlidogyrus cubitus	157	152	96.82	14.3±1
Cichlidogyrus ergensis	157	148	94.27	11.7 ±0.2
Cichlidogyrus vexus	157	112	71.34	10.6 ±0.5
Cichlidogyrus anthemocolpos	157	78	49.68	8 ±1,2
Cichlidogyrus dossoui	157	66	42.04	8.3±0.3
Cichlidogyrus digitatus	157	51	32.48	6.4 ±0.1

Table-2: Prevalence and mean intensity of gills Monogenean parasite species according to seasons

Parasite species	Seasons	% Prevalence	Mean Intensity ± Standard Error
Cichlidogyrus cubitus	Rainy	92.6	12.8±0.4
	Dry	33.9	7.1±2
Cichlidogyrus ergensis	Rainy	83.4	10.6±1
	Dry	39.8	5.66±0.2
Cichlidogyrus vexus	Rainy	86.2	11.1±0.5
	Dry	37.2	5.04±0.1
Cichlidogyrus anthemocolpos	Rainy	48.16	7.2±2
	Dry	22.35	4.02±1
Cichlidogyrus dossoui	Rainy	49.54	6.9±0.1
	Dry	19.2	3.3±0.4
Cichlidogyrus digitatus	Rainy	33.6	5.6±1
	Dry	17.16	2.6±0.3

Table-3: Fulton condition factor (K) (g/cm^3) of infected and uninfected by gills Monogenean parasites of Hybrid (Coptodon zillii x C. guineensis) according to seasons.

Status	Parameters	Seasons	
		Rainy	Dry
No parasitized	Total Length (cm) mean±SE	19.78±1	19.66±0.5
	Weight (g) mean±SE	67.32±1.6	48.63±0.9
	Condition Factor (K) (g/cm^3) mean±SE	0.87±0.14	0.64 ±0.01
Parasitized	Total Length (cm) mean±SE	19.84±1.3	19.43±1.2
	Weight (g) mean±SE	40.61±0.8	35.20±0.2
	Condition Factor (K) (g/cm^3) mean±SE	0.52±0.1	0.48±0.02

Table-4: Prevalence and mean intensity of gill Monogeneans according to the Hybrid (Coptodon zillii x C. guineensis) sex.

Host sex	Male		Female		Combined	
Hosts examined	77		80		157	
Parasites species	P (%)	IM ± SE	P (%)	MI ± SE	P (%)	MI ± SE
Cichlidogyrus cubitus	97.22	13.2±2	33.18	4.8±0.2	78.2	11.6±0.7
Cichlidogyrus ergensis	82.91	11.9±1	41.5	5.4±0.3	67.9	10.8±0.4
Cichlidogyrus vexus	36.9	6.3±0.8	78.7	12.6±1	63.8	10.2±0.8
Cichlidogyrus anthemocolpos	28.7	5.8±0.7	45.2	9.6±0.4	43.51	8.9±1
Cichlidogyrus dossoui	22.81	4.82±0.1	47.3	9.52±0.1	39.7	7.3±1.4
Cichlidogyrus digitatus	28.63	4.9±0.5	39.1	5.4±0.3	32.43	4.1±0.2

P: Prevalence; MI; Mean Intensity; SE: Standard Error.

Table-5: Fulton condition factor (K) (g/cm^3) of infected and uninfected by gills Monogenean parasites of Hybrid (Coptodon zillii x C. guineensis) according to sex.

Status	Parameters	Male	Female	Combined sex
No parasitized	Total Length (cm) mean ± SE	19.72±1	18.5±0.6	19.2±0.4
	Weight (g) mean ± SE	62.11±1.2	55.08±1.06	62.99±0.3
	Condition Factor (K) (g/cm^3) mean ± SE	0.81±2	0.87±0.06	0.89±0.13
Parasitized	Total Length (cm) mean ± SE	19.58±1.3	18.3±0.2	19.02±1
	Weight (g) mean ± SE	38.28±1.8	19.61±1.4	26.14±1.1
	Condition Factor (K) (g/cm^3) mean ± SE	0.51±1.6	0.32±0.02	0.38±0.2

Table-6: Prevalence and mean intensity of gill Monogeneans according to the Hybrid (Coptodon zillii x C. guineensis) size.

Standard Length (cm)	Examined hosts	Prevalence (%)	Mean Intensity ± Standard Error
14-16.9	40	33.6	4.18±03
17-19.9	39	43.12	6.21±1
20-22.9	40	88.54	8.6±0.2
23-25.9	38	96.23	12.63±1

Table-7: Fulton condition factor (K) (g/cm^3) of infected and uninfected by gills Monogenean parasites of Hybrid (Coptodon zillii x C. guineensis) according to size.

Status	Parameters	Length class (cm)			
		14-16.9	17-19.9	20-22.9	23-25.9
No parasitized	Total Length (cm) mean ± SE	15.3±0.2	18.6±1.02	21.12±0.4	24.1±1.6
	Weight (g) mean ± SE	30.08±0.1	48.90±1.7	76.30±2.1	116.18±3
	Condition Factor (K) (g/cm^3) mean ± SE	0.84±1.3	0.76±0.6	0.81±0.4	0.83±1.1
Parasitized	Total Length (cm) mean ± SE	15.1±0.3	18.4±1	21.09±0.2	24.07±2.3
	Weight (g) mean ± SE	10.46±0.8	21.18±0.6	39.40±2.1	66.94±1.4
	Condition Factor (K) (g/cm^3) mean ± SE	0.31±0.02	0.34 ±0.01	0.42±0.1	0.48±0.02

Discussion: The gill parasitofauna of the Hybrid (*Coptodon zillii* x *C. guineensis*) in sector IV of the Ebrié lagoon revealed six (6)Monogenean species of the genus *Cichlidogyrus*. Simkova *et al*.[17] found 4 species of the Hybrid of *Cyprinus carpio* and *Carassius gibelio*.Parasite richness can be influenced by various factors, including host characteristics, behavior and habitat[18]. However, more contextual elements such as sampling effort could influence parasite richness as noted by Walther *et al*.[19]. Furthermore, host and parasite phylogeny also play a determining role in species diversity[16,20]. In addition, water quality, influenced by environmental factors, directly affects parasite ecosystems[21]. The high number of parasite species obtained in this study could be attributed to the specific ecological conditions of the areas that influence the composition and abundance of parasites as mentioned by Zharikova[22].

The maximum values of the parasite indices of all the parasite species collected were recorded in the rainy seasons. Similar results have already been obtained by Adou *et al*.[23] and 1Blahoua *et al*.[1,24] with the gill parasites of *Tilapia guineensis* and *Sarotherodon melanotheron*, *Tilapia zillii*, *Oreochromis niloticus*. Several parasites have free-living stages (eggs, larvae, or both) where they are exposed to the external environment (ectoparasites). The increase in parasite infestation of hosts during the rainy season observed in the present study could be attributed to the weakened immune system of fish. Indeed, during the rainy season, the aquatic environment is contaminated by domestic wastewater discharges and drainage from runoff water from agricultural products (phytosanitary products), thus making aquatic organisms vulnerable to parasitic infestation as noted by Kemp and Spotila[25]. In this lagoon, the fishing technique "accadja enclos" is practiced a lot. It consists of making enclosures with branches and wood from trees that are immersed in water to promote the reproduction and growth of fish. During the rainy seasons, this practice of accadja enclos favors an accumulation of organic matter. Excessive accumulation of organic matter reduces water circulation, leading to a decline in water quality and thus favorsa fish infestation by the parasites. The condition factor (K) which is described as a morphometric index necessary to assess the physiological condition of fish based on the fact that individuals of a given length that have a higher mass are in better condition was studied. In general, infested fish are leaner than uninfested ones. This is explained by the fact that parasitic infection leads to the loss of nutrition and energy in infected individuals. In addition, parasitic infections increase the sensitivity of their hosts to various other stress factors that can reduce their weight[26].

However, within parasitized fish, the conditions were roughly the same for both seasons. Indeed, during rainy seasons, the waters became more oxygenated and a large amount of food is available for the fish. These new conditions, in addition to the heavy parasite infestation, can stabilize the body weight of infected hosts.

Parasitic infestations in Hybrid showed differences depending on the parasite species and the host fish sex. Some Monogenean species (*Cichlidogyrus cubitus* and *C. ergensis*) showed a preference for the male sex and others such as *C. vexus*, *C. anthemocolpos* and *C. dossoui* for female hosts. The explanations given in the literature regarding the relationship between sex and parasite infestation are contradictory, with some indicating a positive correlation and others showing the opposite[27-30]. The difference in infestation between male and female fish could be attributed to differential feeding either in terms of the quantity or quality of food ingested or due to different degrees of resistance or infection as demonstrated by Emere[31]. This study indicated that infected female hybrids were skinny than male hybrids. This could be attributed to the physiological state of the female. Indeed, most pregnant female fish have reduced resistance to parasite infection[32].

Gill parasite infestation of this fish increased with host size. Several authors have found a positive relationship between parasite load and host size[30,33]. These observations were due to the fact that larger hosts accumulated more parasites due to continuous exposure to infestation over time. Furthermore, the larger the fish, the more susceptible it is to parasitic infection, as adult fish consume a wide variety of foods and exhibit a variety of feeding styles, thus exposing them to parasitic infestation. In uninfected fish, all hosts of different size classes had a condition factor less than 1 ($K < 1$) indicating that the fish were in poor physiological condition due to the different environmental stressors exerted on them. The condition factor (K) in infected fish increased from small to large fish. Smaller infected fish were much thinner than larger ones. This could be due to the low level of immunity present in this group of fish. This makes them more vulnerable because they have not yet developed a robust defense system to combat polyparasitism.

Conclusion

Parasitism and condition factor of the hybrid (*Coptodon zillii* x*C. guineensis*) was studied in sector IV of the Ebrié lagoon. Six species of gill Monogenean were identified on the fish. These were *Cichlidogyrus cubitus*, *C. ergensis*, *C. vexus*, *C. anthemocolpos*, *C. dossoui* and *C. digitatus*. This study revealed that factors such as seasons of the year, size and sex of the host influence the infestation of Hybrid fish. Also, parasitic infection has a negative effect on the condition factor of the fish, making them even skinny.

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