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Distribution of two monogeneans gill parasites from *Clarotes laticeps* (Ruppell, 1829) in Bagoué river, Côte d'Ivoire

Bouah Enoutchy Fabrice, Gogbé Zeré Marius and N'Douba Valentin

Abstract
The distribution of two monogeneans species, *Protoancylodiscoides essetchii*, and *P. ivoiriensis*, gill parasites of *Clarotes laticeps* (Ruppell, 1829) was studied in the Bagoué River. The parasites were collected and mounted according to each sector of the gill arch. The determination of the different monogeneans species was carried out using a binocular loupe and a microscope. 1584 *P. essetchii* and 576 *P. ivoiriensis* were collected. All monogenean parasites increased with the size of the fish. *P. ivoiriensis* were higher in female fish. No preference was observed in the distribution of parasite species relative to the left and right sides of the host. *P. essetchii* prefers the gill arches I, II, and III and the dorsal and medial segments. *P. ivoiriensis* was found on the gill arches IV and ventral segments. Also, these two monogenous species showed a negative correlation with the parasite density and condition factor of *Clarotes laticeps.*

Keywords: distribution, Monogenean, *Protoancylodiscoides,* condition factor, *Clarotes laticeps,* Bagoué river

1. Introduction

Fish are a resource of great nutritional value. As the availability of animal proteins on the market is problematic, continental fish farming aims to diversify and even supplement protein supplies for human consumption, but also to meet growing needs [1]. Several studies have identified several species within the Siluriformes that have good potential for aquaculture. *Clarotes laticeps* (Rüppell, 1829) is a species abundantly fished and commercialized in the Bagoué River. *C. laticeps* has a high potential for aquaculture [2] due to its biological characteristics namely: robust body, omnivorous diet, ability to live in hypoxic conditions, high fecundity [3]. This fish has a continuous reproduction and a high growth rate and above all its considerable size, i.e. a maximum standard length of 80 cm for a weight of 10 kg [4]. Under farming conditions, parasitism due to monogeneans can affect host growth and reproduction, leading to a weakening of the host immune system, increased susceptibility to secondary infections, nutritional devaluation of the fish, and even fish kills resulting in significant economic losses [5, 6, 7, 8]. The increased density of fish populations in facilities facilitates the spread and/or transfer of parasites to unusual hosts [9]. To prevent epizootics that may affect fish reproduction and health, specific studies should be conducted on the parasitic fauna of native fish species before any domestication [10]. Furthermore, to prevent the transfer of introduced parasites, which are often more pathogenic [10] recommends the use of native rather than non-native species for domestication. According to the Food and Agriculture Organization of the United Nations (FAO) [11] to meet the increasing demand for freshwater fish, extensive research must include studies of their parasites to optimize production levels. Furthermore, knowledge of fish parasites is of particular interest not only for fish health but also for understanding ecological problems [12, 13]. In Africa, data on the distribution of monogeneans according to different sectors or parts of the gills in *C. laticeps* are almost non-existent. In Côte d'Ivoire, the only data available on the parasitic infestation of *C. laticeps* are those of [14], which describe two new *Protoancylodiscoides* gill parasites of *C. laticeps* in the Bagoué River. The present study aims to understand the cohabitation between two species of gill parasites of *C. laticeps* in the Bagoué River. It analyses the rate of infestation as a function of fish size, sex, host sides, transverse and longitudinal gill gradient. It also assesses the impact of monogeneans on the health of this species in this river.

2. Materials and Methods

2.1. Sampling area

The Bagoué river, transboundary between Côte d'Ivoire and Mali. Is located in the northwest of Côte d'Ivoire between longitudes 5°40' and 7°10' West and latitudes 9°15' and 10°50' North [15]. It originates in Kokoum, in the Madinani region of Côte d'Ivoire at an altitude of approximately 600 m [16]. From the source to the Ivorian-Malian border, its length is 230 km long, with a basin of about 10150 km^2 [15]. On Ivorian territory, the Bagoué receives several tributaries, the two main ones being the Palée on the left bank and the Niangboué or Gbangbè on the right bank [17]. The Bagoué River is subject to the Sudano-Guinean climate characterized by two seasons: a rainy season from May to October and a dry season from November to April [18, 19]. In this study, three sampling sites in Samorossoba (6º21'W; 9º52'N); Samorosso (6º30'W; 9º34'N) and Guinguéreni (6º35'W; 9º32'N) (Figure 1) were defined on this river, taking into account their accessibility, their environmental characteristics, and the availability of fish at all times.

2.2. Fish and gill sampling

This study focused on a total of 133 specimens of *C. laticeps* caught with gillnets from August 2018 to July 2019. The fish were identified according to [20]. Measurements were made to the nearest millimeter using a graduated ichthyometer. The size classes in interval steps (10 cm) were defined to have a representative size [10]. The sex of the fish was determined after the identification of the gonads. The left and right gill arches were sampled by two sections: one dorsal and the other ventral. These were labelled according to the fish and sides (left or right) and then kept in ice (0°C) until they were taken to the laboratory where they were conserved in the refrigerator.

2.3 Research and Identification of Monogeneans

In the laboratory, the gill arches were detached and numbered from I to IV in the anteroposterior direction following the transverse gradient [21]. Each gill arch was divided dorso-ventrally into three sectors along the transverse gradient [21] (Figure 2). The sectors thus obtained were examined separately and the collected parasites were mounted between blade and lamina in a drop of ammonium picrate glycerol [22]. Observations were made using a *Motic BA310* optical microscope with an integrated camera. The identification of the parasites is based on the morphology and size of the sclerified pieces of the haptor and the copulatory organs.

2.4 Ecological analysis

The prevalence, abundance, and mean intensity were defined according to [23]. Parasite species were classified as dominant if (prevalence > 50%), satellite if (10 ≤ prevalence ≤ 50%) or rare if (prevalence < 10%) according to [24]. Concerning the mean intensity, the classification of species adopted is that of [25]. The mean intensity (MI) is very low if (MI ≤ 10), low if (10 ≤ MI ≤50), medium if (50 ≤ MI ≤ 100), and high if (MI > 100). Fulton's condition index (K) was used to see the overweight of the host and assess the influence of monogeneans on the host. It is the ratio between the total weight of the fish and the corresponding size. It is given by the following relationship [26]:

$$K = \frac{Pt}{LS^3} \times 100$$

K, Pt, and LS being respectively the condition factor, the total weight of the fish (g), and the standard length of the fish (cm).

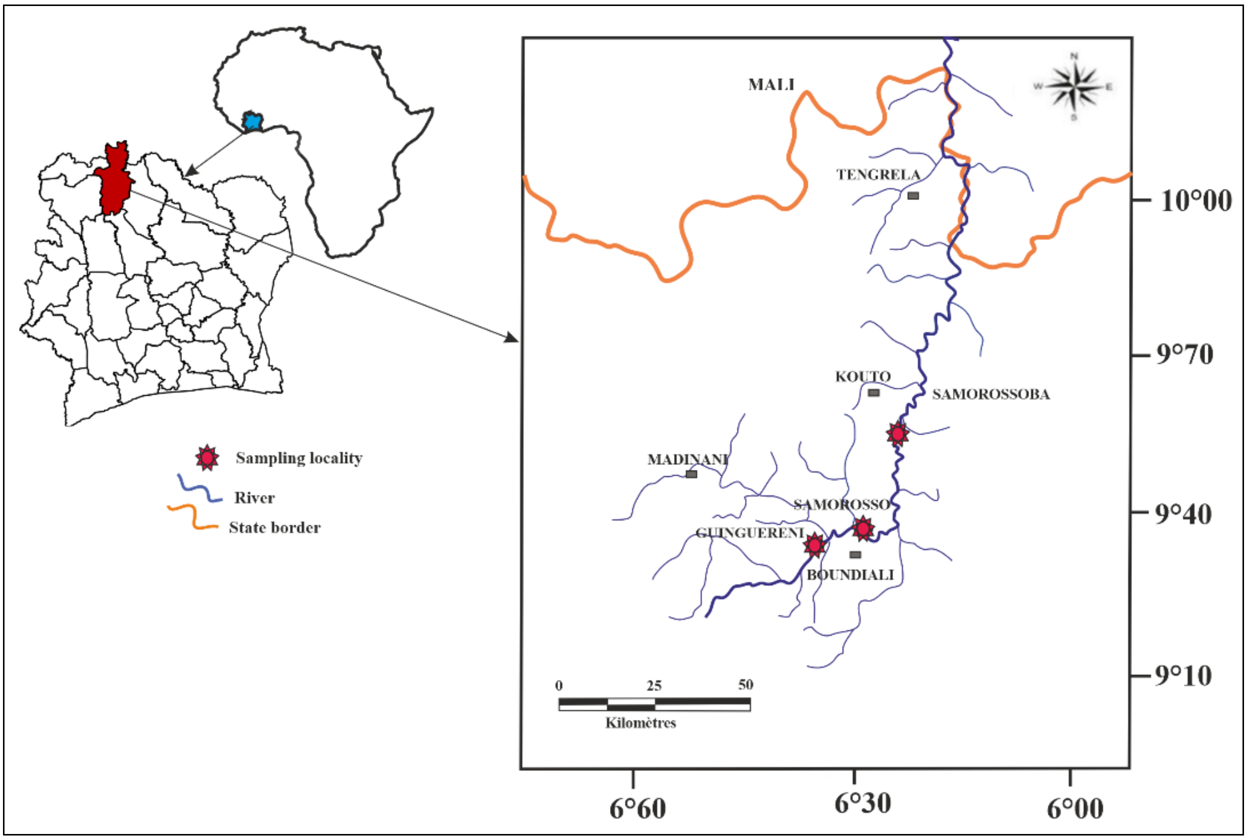

Fig 1: Geographical location of the Bagoué River (Côte d'Ivoire) and sampling sites.

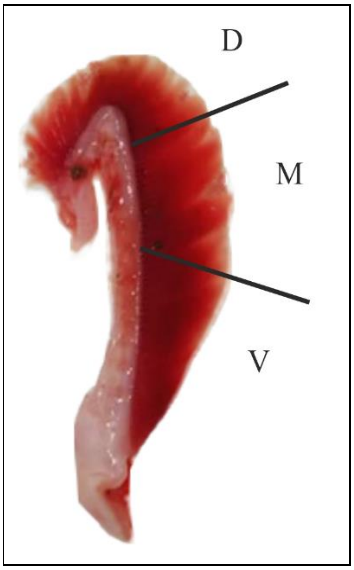

Fig 2: Division of branchial arch *Clarotes laticeps* D : dorsal segment ; M : medial segment : V : ventral segment.

The parasite density (d) is the number of parasites per unit mass of fish [27].

$$d = \frac{np}{m}$$

np and m being respectively the number of parasites and the mass (g) of the fish.

2.5 Statistical analysis

The Chi-square (χ2) was used to compare two or more proportions (prevalence) of monogenean between size classes. The Mann-Whitney (U) test was used to compare the parasite intensity and abundances of different monogenean species according to host side and sex. The Kruskal Wallis (K) test allowed a comparison of the intensity of more than two samples. Differences of $p<0.05$ were considered significant. All statistical analyses were performed using XLSTAT software.

3. Results

3.1 Monogenean species composition

Examination of the gills of 133 specimens of *C. laticeps* (66 males and 67 females) allowed the collection of 2160 parasites divided into two species of Monogeneans: *Protoancylodiscoides essetchii* Bouah, N'Douba et Pariselle, 2021 (1584 specimens), and *Protoancylodiscoides ivoiriensis* Bouah, N'Douba et Pariselle, 2021 (576 specimens) (Table 1). *P. essetchii* with a prevalence of 93.98%, represents the dominant species of this xenocommunity. *P. ivoiriensis* with a prevalence of 48.87% represents the satellite species. The respective values of the mean intensity obtained are 12.67 and 9.14. This mean intensity is low for *P. essetchii* while it is very low for *P. ivoiriensis.*

3.2 Variation of Parasitism according to the length classes of *Clarotes latiseps*.

The size-dependent parasitism analysis of *C. laticeps* was carried out on 133 fish specimens. The standard length range was 15-55 cm. Figure 3 shows that all size classes of *C. laticeps* harbor the Monogenes parasites. For both parasites, the minimum prevalence and average intensity are recorded in the small size individuals 15 ≤ LS ≤ 25 cm. The maximum prevalence of *P. essetchii* (100%) and *P. ivoiriensis* (69.69%) was recorded in large individuals 45 ≤ LS ≤ 55 cm (Figure 4). The observed differences in the prevalences of *P. ivoiriensis* and *P. essetchii* at the level of size classes were significant (Chi square, χ2 = 26.89 and 132.80 df = 1; p =0.00 < 0.05). Also, the application of the Kruskall-Wallis (K) test to the mean intensities shows that the infestation of the different Monogenes species is dependent on host size (p<0.05).

Table 1: Prevalence (%) and Mean intensity (MI)±SE of the two *Protoancylodiscoides* species fo *Clarotes laticeps* sampled in the Bagoué River

Species of Parasites	Number of examined fishes	Number of infected fishes	Number of parasites	P (%)	(MI)±SE
P. essetchii	133	125	1584	93.98	12.67±1
P. ivoiriensis	133	63	576	48.87	9.14±0.2

SE: Standard Error

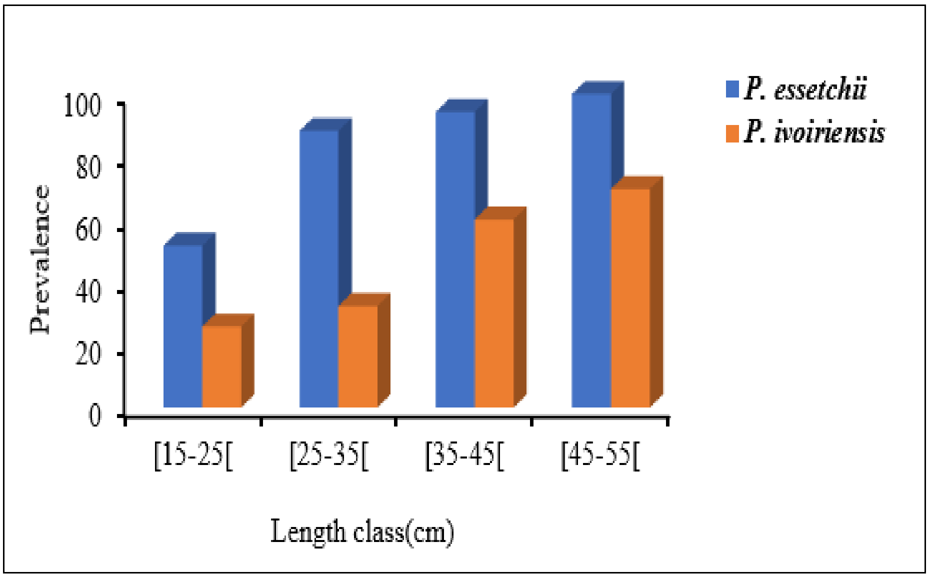

Fig 3: Prevalence (%) of the two *Protoancylodiscoides* species as a function of the length class

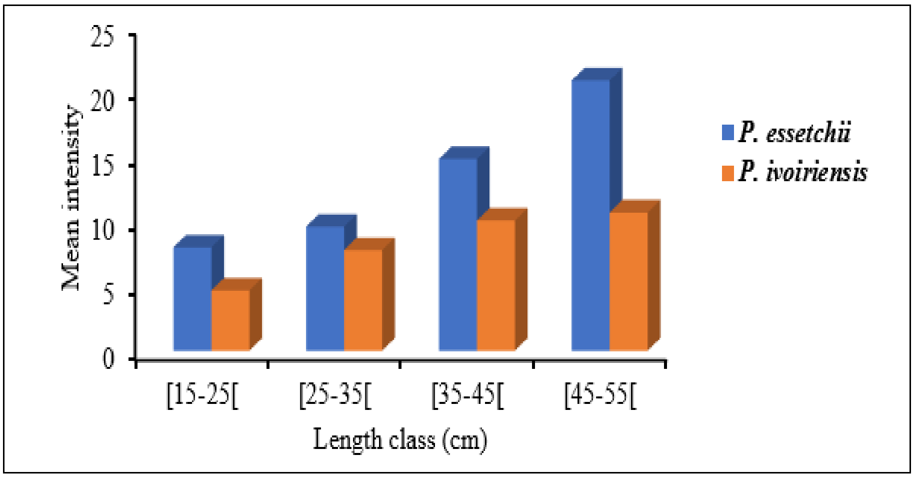

Fig 4: Mean intensity of the two *Protoancylodiscoides* species as a function of the length class

3.3 Variation of Parasitism according to the sex of *Clarotes latiseps*.

The analysis of parasite indices according to the sex of *C. laticeps* is shown in Figure 5. Examination of male hosts showed that 47.37 and 16.54% were infested by *P. essetchii* and *P. ivoiriensis* respectively. In female hosts, 46.62 and 38.35% were respectively infested by *P. essetchii* and *P. ivoiriensis*. The Chi-square test of independence shows that there is no significant difference ($\chi 2$ = 13.6 df = 1; p =0.4 > 0.05) between the prevalences of *P. essetchii*. The Mann-Whitney U test (p = 0.1 > 0.05) indicates that the sex of the host has no significant impact on the infection of *C. laticeps* by *P. essetchii*. In contrast, the difference is significant ($\chi 2$ = 36.21; df = 1; p = 0.00 < 0.05) for *P. ivoiriensis*. The mean intensities (Figure 6) are 12.25 and 4, in male hosts for *P. essetchii* and *P. ivoiriensis* respectively. In female hosts, the mean intensities are 13.10 and 9.29 for *P. essetchii* and *P. ivoiriensis* respectively. The Mann-Whitney U test (p = 0.002 < 0.05) applied to the parasite indices shows that the infestation of *C. laticeps* by *P. ivoiriensis* is higher in female hosts.

3.4 Variation of Parasitism according to the Right and Left Gills, Gill Arches, and Gill Arch Segments

From 133 individuals of *C. laticeps* examined, 125 and 63 hosts are infested by *P. essetchii* and *P. ivoiriensis* respectively (Table 2). Analysis of this parasite fauna showed that the right and left gills harbor 844 and 740 individuals of *P. essetchii* and 298 and 278 specimens of *P. ivoiriensis* respectively. The Mann-Whitney U test (p = 0.5 > 0.05) applied to the average parasite intensities shows that the right and left gills of *C. laticeps* are infested in the same way. These parasites, therefore, exploit right and left gills in the same way. The distribution of Monogenes according to the transverse gradient in *C. laticeps* (Figure 7) reveals that *P. essetchii* adopting anteroposterior colonization prefers gill arches I, II, and III over arch IV. (Kruskal Wallis test (p<0.05). In contrast, P. ivoiriensis colonised more gill arches IV and III compared to arches I and II (Kruskal Wallis test (p<0.05). Evaluation of *C. laticeps* parasitism as a function of longitudinal gradient (Figure 8) indicates that *P. essetchii* preferentially colonizes dorsal and medial segments (Kruskal Wallis test (p<0.05) while, *P. ivoiriensis* colonizes more ventral segments (Kruskal Wallis test (p<0.05).

3.5 Impact of parasitism on the condition factor of *Clarotes latiseps* in the Bagoué River

Parasitism as a function of condition factor of *C. latiseps* (Figure 9) shows that as parasite density increases, the physiological condition of the fish decreases, indicating a negative relationship between parasite infection and the health status of the host fish (K = -0.0158d + 0.2358; r^2 = 0.0051; p = 0.0026). This suggests that the growth of *C. laticeps* is negatively affected by the density of parasites in the Bagoué River.

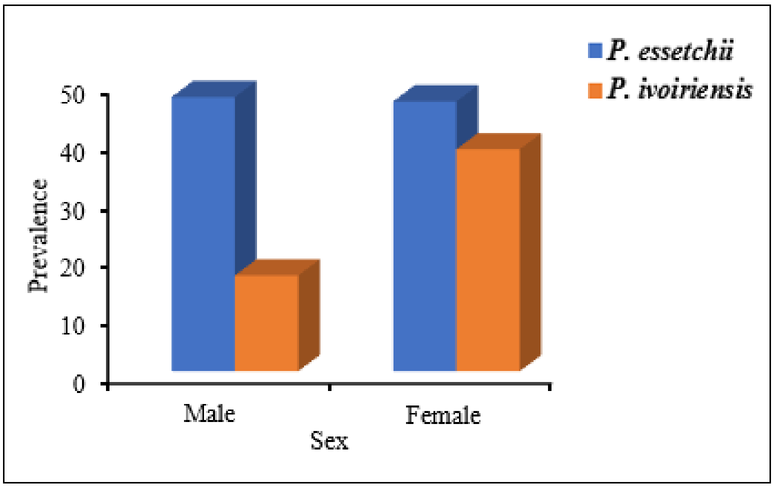

Fig 5: Prevalence (%) of the two *Protoancylodiscoides* species as a function of the sex of *Clarotes latiseps*

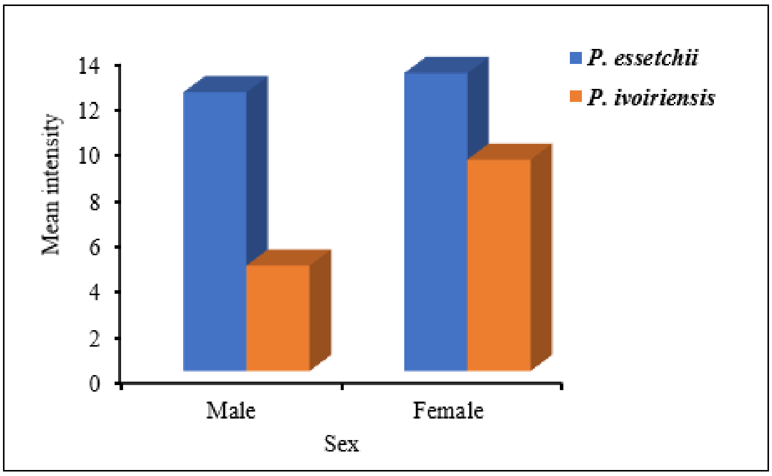

Fig 6: Mean intensity of the two *Protoancylodiscoides* species as a function of the sex of *Clarotes latiseps*

Table II: Infestation of the left and right gills of *Clarotes laticeps*.

Number of parasites						
Species of Parasites	**Number of examined fishes**	**Number of infected fishes**	**RG**	**MI±SE**	**LG**	**IM±SE**
P. essetchii	133	125	844	6.75±1.2	740	5.9±1
P. ivoiriensis	133	63	298	4.58±0.3	278	4.3±0.2

LG = Left Gill ; RR = Right Gill ; MI = Mean intensity ; SE: Standard Error

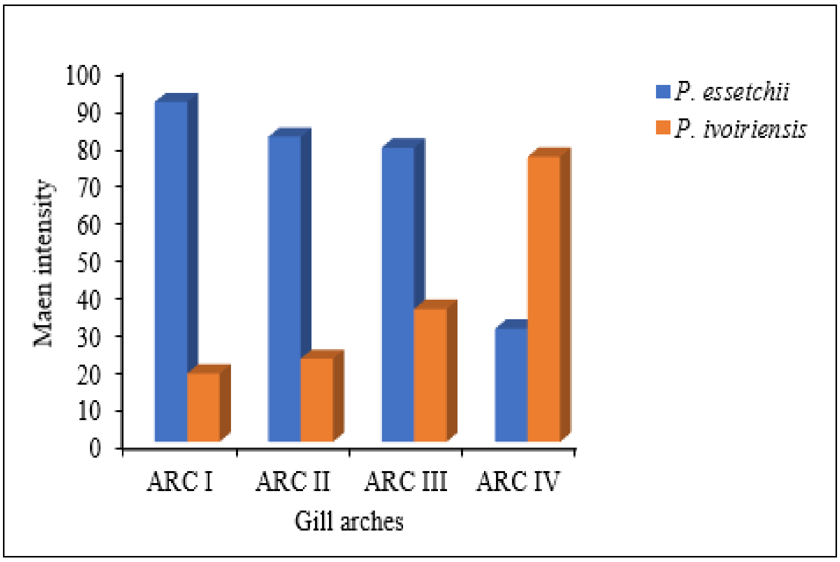

Fig 7: Distribution of two species of *Protoancylodiscoides* according to the gill arches

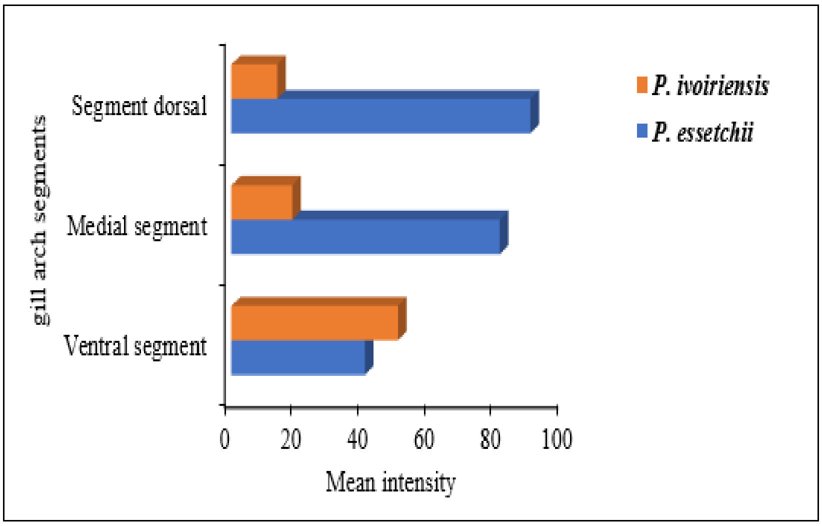

Fig 8: Distribution of two species of *Protoancylodiscoides* as a function of gill arch segments

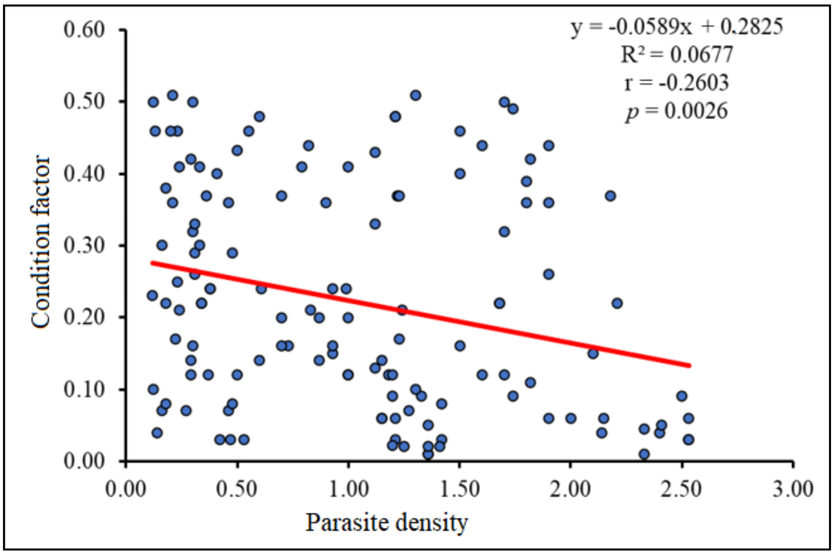

Fig 9: Variation of the condition factor of *Clarotes laticeps* as a function of the parasite density.

4. Discussion

This study revealed the simultaneous colonization of the gills of *C. laticeps* captured in the Bagoué River by two Monogenean species. The presence of these Monogeneans has already been reported by Bouah *et al*. [14]. In Côte d'Ivoire, polyparasitism of fish by Monogenean gill parasites is very well documented Blahoua *et al*. [28, 29, 30]; Adou *et al*. [31, 32]. This multispecific parasitism of *C. laticeps* could be explained by the permanent presence of vacant niches on its gill biotope. Analysis of parasite loads showed that the infestation of *C. laticeps* by *P. essetchii* and *P. ivoiriensis* increases with the size of the host fish. Similar observations have been reported by various authors. For instance, Tombi *et al*. [33] noted that in *Barbus camptacanthus* the mean intensity of *Dactylogyrus amieti* and *Dogielius njinei* were maximum in individuals with a standard length greater than 75 mm. Similarly, Blahoua *et al*. [28, 34, 29] showed that in *Sarotherodon melanotheron*, *Copodon zillii*, and *Oreochromis niloticus*, larger specimens harbored more parasites than smaller ones. These same observations have been reported in *Coptodon zillii* in Lake Ayamé 2 [31]. The increase in parasite load with the fish size is due to the increase in the number and surface area of gill filaments [35]. In fact, this would provide an increased large surface for parasites, which would favor their higher numbers in larger hosts. Furthermore, the large surface area of the gills in large specimens increases the volume of water that passes through them [36]. Indeed, the high volume of water passing through the gills of these specimens increases the chances of invasion of the parasitic Monogeneans lava (Oncomiracidium). Also, larger fish would have had more time to accumulate parasites [37, 35].

The study revealed that *P. essetchii* parasites of *C. laticeps* have no preference for the sex of their host. These observations coincide with those of Blahoua *et al*. [34, 29] who pointed out that Monogenean parasites of *Coptodon zillii* and *Oreochromis niloticus* have no preference for the sex of the host. Also, Adou [38] observed that infestation of *Sarotherodon melanotheron* by *Cichlidogyrus acerbus*, *C. halli*, and *Scotugyrus minus* is independent of host sex. All these observations are supported by the idea that very few Monogeneans have a host sex preference [39]. In contrast to *P. essetchii*, *P. ivoiriensis* parasites infest more female hosts. These observations corroborate those of Kir [40,] and Lizama *et al*. [41] showed that the Monogenean *Dactylogyrus extensus* and *Tereancistrum curimba* were more abundant in females of *Cyprinus carpio* and *Prochliodus lineatus*. Also, Ibrahim [35] observed that the prevalence and the mean intensity of *Cichlidogyrus arthracanthus* and *C. aegypticus*, *C. tiberianus* and *C. tilapiae* were higher in female hosts. Adou [38] noted that *Cichlidogyrus cubitus*, *C. ergensis*, and *C. anthemocolpos*, gill parasites of *Coptodon zillii*, and *C. vexus* parasites of *Coptodon guineensis* were more abundant in female hosts. The high intensity of parasites observed in female hosts is thought to be related to their reproductive period. Females are more susceptible to parasite infection in periods of gonad development [42, 35]. For Ibrahim and Soliman [43], these results also may be attributed to the immune response of the host due to the activities of the endocrine glands between the male and the female host fishes. Indeed, during this period, females increase in size offering a larger surface area for parasite attachment [42, 35]. According to Bilong Bilong [10], during the oviposition phase, some females huddle in rock cavities and become more sedentary. This behavior change is conducive to an increase in the parasite. In general, the distribution of gill parasites of *C. laticeps* from the Bagoué River does not differ between the left and right sides of the host. Similar observations were made by other researchers such as Blahoua *et al*. [29]; Agos [44]; Lim *et al*. [45] on the gill of *Oreochromis niloticus*. Examination of various other fish species such as *Coptodon zillii*, *C. guineensis*, the hybrid (*C. zillii* X *C. guineensis*), and *Sarotherodon melanotheron* by Adou [38], gave the same results. For Tombi *et al*. [33], this equipartition of Monogenean on either side of the host's gills would be due to the bilateral symmetry of its body. Thus, the bilateral symmetry of the body of *C. laticeps* would explain the equitable distribution of parasites on the left and right sides of the fish. This work revealed that in *C. laticeps*, *P. essetchii* is more abundant on gill arches I, II, and III, and *P. ivoiriensis* exploit more the gill arch IV. Several cases of gill arch preference by Monogenean have been reported. Indeed, according to Dzika [46], *Pseudodactylogyrus anguillae* has a preference for the median (II and III) gill arches of *Anguilla anguilla*. This is also the case for gill parasitic Monogenean of *Oreochromis niloticus* [29, 47]. Adou [28] noted that gill arches II and III are simultaneously more infested by *Cichlidogyrus vexux* in *Coptodon zillii*, by *C. ergensis* and *C. louipaysani* in *C. guineensis*, and by *Scutogyrus minus* in *Sarotherodon melanotheron*. Besides, Nack *et al*. [48] reported the preference of arc IV of *Clarias camerunensis* by *Quadriacanthus pariselli* and *Birgiellus kellensis*. Several hypotheses are often put forward to explain the selection of branchial arches by parasitic Monogeneans. According to Gutiérrez and Martorelli [49]; Lo and Morand [50] median gill arches II and III are more infested because they receive a greater volume of water and a strong ventilatory current-carrying more infesting larvae. The high infestation of these arches is also because they offer the parasites a large surface area to colonize [51, 52]. The low rate of infestation of arc I observed would result from the mode of colonization of the host by the Monopisthocotylea lava [53, 54]. According to these authors, the oncomiracidium first attach themselves to the body of the fish and then migrate towards the gills. Thus, they first reach arch IV and gradually arch III, II, and I. At the level of the longitudinal gradient, the results obtained revealed that in *C. laticeps*, *P. essetchii* preferentially colonizes the dorsal and medial segments, while *P. ivoiriensis* colonize more the ventral segments.

The preference of Monogeneans for specific places in the gill arches has been the subject of much investigation. [38, 48, 50, 55, 56,]. For these authors, the parasites colonize the sectors independently. Some settle on the median sectors more exposed to the respiratory water current while others, in rare cases, attach themselves to the dorsal or ventral sector. Several interpretations explain the choice of gill sectors by parasitic Monogeneans. For Bilong Bilong [10], some species attach themselves essentially to the medial sectors because these are more exposed to the ventilatory current. Biotic factors such as the shape and size of the sclerified pieces of the haptor also play an important role in the choice of attachment sites [53,57]. These authors believe that Monogenean armed with small anchors preferentially attach to the ventral region of the gill filaments to take shelter from the strong current. On the other hand, other authors think that the preference of certain sites by monogenean is linked to intra- and interspecific competition [58]. The most plausible hypothesis for the choice of gill arch segments in the genus *protoancylodiscoides* is probably the size of the sclerified pieces (dorsal and ventral anchors) of the haptor. Indeed, *P. essetchii* has larger dorsal and ventral anchors than *P. ivoiriensis*, hence the resistance of these species to water currents on the dorsal and median arches.

The correlation between condition factor (k) and parasite density (d) revealed that parasitism harms the health of *Clarotes laticeps* in the Bagoué River. Marinho *et al*. [59] also observed a negative correlation between overweight and parasite density of *Dawestrema cycloancistrium* and *D. Cycloancistrioides* parasites of *Arapaima gigas*. Similar observations were made by Lizama *et al*. [60] with the monogeneans *Cichlidogyrus sclerosus* and *Cichlidogyrus* sp. On the gill of *Oreochromis niloticus*. For these authors, the negative impact of the parasites on fish health is evidence of their pathogenicity on the fish gills. Indeed, during this work, the *Clarotes laticeps* specimens sampled produced large quantities of mucus. This increased production of mucus could be due to the high parasite density, which would be a way for these fish to fight against these parasites. Paredes-Trujillo *et al*. [61] argue that although parasites do not kill fish, they still produce a subtle and important debilitating effect on the host.

5. Conclusion

This study, which is the first in-depth study on the distribution of microhabitats of branchial parasitic monogeneans of *C. laticeps* in the Bagoué River, is a contribution to the understanding of the spatial distribution of monogeneans of this species. The results showed that parasitic indices increase with host size. The gills of the right and left sides as well as those of both sexes are equally likely to be infested. However, the distribution of these two monogenean species across the gill arches and segments differs between *P. essetchii* and *P. ivoiriensis*. Thus, the preference for specific parts of the gill arches of *C. laticeps* would be a way for these parasites to limit interspecific competition. This study also showed that parasitic monogeneans hurt the physiological condition of the host. The information obtained may provide strategies in aquaculture management to reduce potential economic losses of *C. laticeps* caused by parasitic infection.

6. Conflict of interest

The authors declare no conflicts of interest

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