Ecological aspects and impact of parasitic gill Copepods on the condition factor of catfish *Chrysichthys nigrodigitatus* from Aby Lagoon (Côte d'Ivoire)

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1 ABSTRACT

Commonly known as the "African catfish," *Chrysichthys nigrodigitatus* is a species widely exploited in West Africa for its economic and nutritional value. In Aby Lagoon (Côte d'Ivoire), this fish inhabits an environment subject to strong anthropogenic and environmental pressures, which favor the establishment of diverse parasitic communities. Among these, gill-infesting copepods represent major ectoparasites capable of affecting fish health and productivity. This study focused on the identification and distribution of three parasitic copepod species: *Ergasilus latus* FRYER, 1960, *E. sarsi* CAPART, 1944 and *Lernaea cyprinacea* LINNAEUS, 1758. The methodology involved sampling fish from two stations (Adiaké department and Aby village), followed by epidemiological analyses (prevalence, mean intensity, abundance) and statistical tests (Chi-Square, Kruskal–Wallis, Mann–Whitney). The results revealed the highest prevalences of the three species *E. latus* (69.91%), *E. sarsi* (43.32%) and *L. cyprinacea* (66.96%) at Aby village station. Mean intensities were 5.64 ± 0.7 for *E. latus*, 4.10 ± 0.3 for *E. sarsi* and 5.41 ± 0.3 for *L. cyprinacea*, with respective abundances of 4.58, 1.84 and 3.79 individual parasite per examined host. Infestation was significantly higher during the rainy season and led to a reduction in the condition factor of parasitized fish, indicating a negative physiological impact. This study highlighted the ecological and sanitary importance of parasitic copepods in Aby Lagoon. It underscores the need for regular parasitological monitoring to safeguard the health of natural and aquaculture stocks, andstocks and opens perspectives on the influence of climatic variability and local practices (such as acadja-culture) on infestation dynamics.

2 INTRODUCTION

Belonging to the family Claroteidae, the catfish *Chrysichthys nigrodigitatus* is one of the most exploited freshwater fish species in West Africa. It plays a strategic role in human nutrition as a major source of animal protein and represents an economic pillar for local communities through its commercialization in both national and international markets (Bédia *et al.* 2017). Renowned for its organoleptic qualities, the flesh of this fish is highly valued, which exerts increasing pressure on natural stocks and raises sustainability concerns (Chikou, 2006; Bédia *et al.* 2017). Moreover, its biological characteristics rapid growth, disease resistance, and ability to thrive under high stocking densities make it a preferred species in aquaculture, contributing to food security and poverty reduction in several African countries (Ekanem, 2000; Affourmou *et al.* 2016). However, despite their importance to humans, the development of this fish resource can be hindered by infestation with parasitic copepods. These are organisms encountered primarily on fish, and more specifically on their gills. These parasites attach to gill filaments, feed on mucus and epithelial cells, and cause respiratory lesions, chronic inflammation, and, in severe cases, fish mortality (Dempster *et al.* 2021). Beyond direct damage, infestations disrupt the overall physiological functioning of the fish, notably its body condition, assessed through the condition factor (K). A reduced condition factor (K) generally reflects chronic stress, insufficient nutrition, or severe parasitic infestation (Oni *et al.* 1983). Considering the considerable socio-economic importance of this species and the demonstrated pathogenic threat posed by these parasites, field investigations are essential before any conservation initiatives. Such studies are necessary to predict and prevent health risks, ensuring the protection of farmed stocks. Several studies have investigated the gill parasitic copepods infecting the silver catfish *Chrysichthys nigrodigitatus*, particularly in Nigeria, where research has focused on the inventory and impact of these pathogenic organisms on fish condition factor, both in general and specifically in *C. nigrodigitatus* (Emmanuel and Aromodiu, 2017; Omeji *et al.* 2022). In Côte d'Ivoire, however, research remains limited. Apart from studies of Adou *et al.* (2025) documenting the prevalence of the parasitic copepods *Ergasilus latus* and *Lernaea cyprinacea* in *Chrysichthys nigrodigitatus* from the Aby Lagoon in relation to water quality, no investigation has yet examined the impact of these pathogens on the condition factor of this species. This knowledge gap is particularly concerning given the ecological trajectory of the Aby Lagoon, which experienced a dramatic stock collapse in 1980–1981, characterized by a marked decline in fish abundance attributable to anthropogenic pressures. These pressures, exacerbated by ongoing demographic growth, continue to drive the degradation of this ecosystem (Kambiré *et al.*, 2014 ; Koulai-Djédjé, 2022). Such environmental deterioration disrupts aquatic habitat integrity and fosters conditions conducive to the proliferation of parasitic copepods. These parasites are known to induce nutritional disorders in fish, ultimately manifesting as a decline in body condition (plumpness). The resultant scarcity of healthy, large-sized individuals is reflected in the near-exclusive capture of smaller specimens, which in turn undermines the livelihoods of fishing communities and local populations whose food security and income depend - directly or indirectly - on fishery resources. The overarching objective of the present study is to generate comprehensive data on the infestation patterns and impacts of parasitic copepods on *Chrysichthys nigrodigitatus*, with a view to informing sustainable fisheries management and enhancing fish stock productivity, thereby contributing to the food security of local communities.

3 MATERIAL AND METHODS

3.1 Study Area: Situated in southeastern Côte d'Ivoire within the Adiaké department, the Aby Lagoon (Figure 1) lies between longitudes 3°00'–3°30' W and latitudes 5°10'–5°30' N, where it forms a natural boundary with Ghana. It covers an area of 424 km². The climate of the lagoon is characterized by four seasons: two rainy and two dry (Brou *et al.* 2005). The long rainy season extends from April to July, while the short rainy season occurs between October and November. The long dry season lasts from December to March, and the short dry season from August to September. Aby Lagoon is mainly fed by the Bia and Tanoé rivers (N'Guessan *et al.* 2013). Communication between Aby Lagoon and the Atlantic Ocean is narrow and shallow. The study area is highly anthropized, with widespread fishing, livestock rearing, and various domestic practices. The peripheral zones of the lagoon are occupied by plantations of oil palm, rubber, coffee, cocoa, cassava, and plantain. Artisanal gold mining, particularly active in the locality of Noé (at the Ghanaian border), represents a major source of potential pollution to the lagoon ecosystem, notably due to the use of mercury (Mensah *et al.* 2021). For the purpose of this study, two stations were selected: Adiaké and Aby village. In both sites, the substrate is dominated by sandy and gravelly deposits.

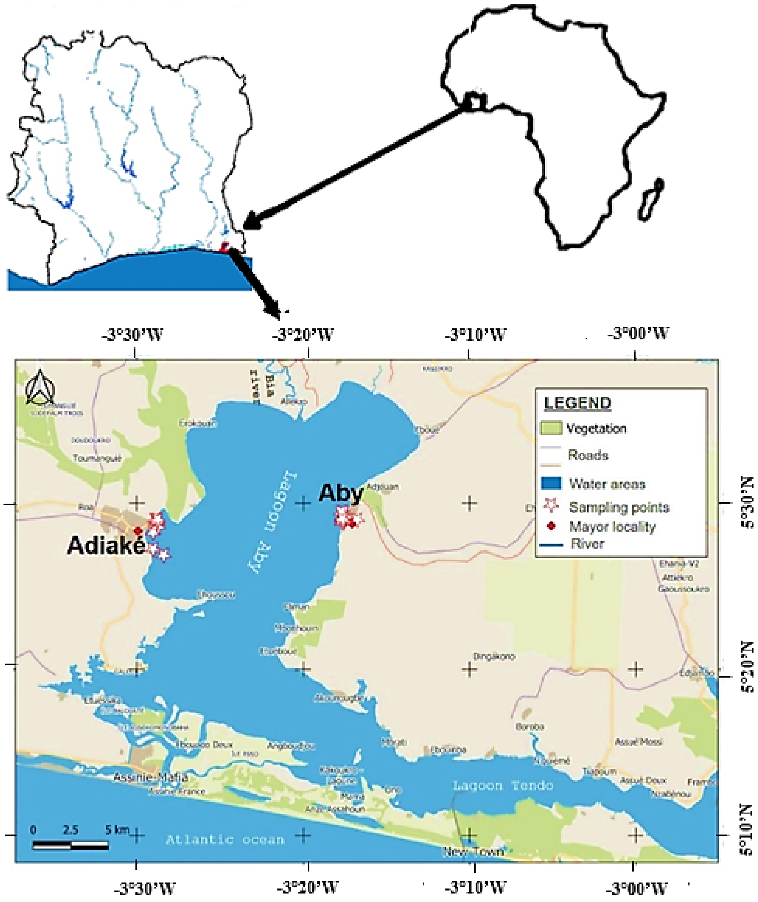

Figure 1 : Map of the sampling stations in the Aby lagoon

3.2 Sampling of Host Fish : Fish specimens (n= 952 specimens) were collected on a monthly basis between March 2024 and February 2025 from the two selected sampling sites, comprising 480 individuals from Adiaké department and 472 from Aby village. The captures were carried out using artisanal fishing techniques, complemented by experimental methods employing gillnets and various gear adapted to the local environmental characteristics. Each specimen was measured for standard length using a calibrated ichthyometer, ensuring millimeter-level precision. This step was intended to establish a reliable morphometric baseline for population analysis. Specimens were weighed with a high-precision electronic balance (Kitchen Scale). Sex determination of the fish was performed by dissection: a mid-ventral incision was made in the abdominal cavity, allowing direct observation of the gonads.

3.3 Collection of gill parasitic Copepods: In the field, the left and right gills of each specimen were excised, carefully labeled according to the host individual, and wrapped in aluminum foil. The samples were then placed in an ice-filled cooler to preserve their biological integrity during transport to the laboratory. Once there, the gills were thawed and carefully dissected to separate the different gill arches. Parasitic copepods attached to the gill tissues were detached by intensive rinsing using a wash bottle filled with distilled water. Collected in a gridded Petri dish, the rinse water was homogenized and examined under a stereomicroscope at ×60 magnification. Parasites were manually isolated using fine forceps and fixed in a 10% formaldehyde solution. After 24 hours of fixation, they were mounted on slides in Canada balsam to allow detailed microscopic observation. Taxonomic identification of copepods was performed following the classical determination keys proposed by Yamaguti (1963) and Kabata (1979). Finally, all collected parasites were counted to assess the parasitic indices and the distribution of copepod species within the studied host populations.

3.4 Epidemiological Approach: Parasitic prevalence (P) was defined according to Bush *et al.* (1997). Prevalence (P) corresponds to the percentages resulting from the ratio between the number of hosts infested (N) by a parasite species and the number of hosts examined (H), calculated as:

$$P = \frac{N * 100}{H}$$

The classification of hosts infested by parasite species follows the framework established by Valtonen et al. (1997). Accordingly, parasite species were categorized as frequent or principal (prevalence > 50%), secondary or intermediate (10% ≤ prevalence ≤ 50%), and rare or satellite (prevalence ≤ 10%).

Mean parasite intensity (IM) is calculated by dividing the total number of individuals of a parasite species (n) by the number of infected hosts (N) in the sample.

$$IM = \frac{n}{N}$$

Abundance (A) is defined as the average number of parasites per host examined, taking into account both those that are infected and those that are not. It represents the mean parasite load across the entire host sample, calculated as:

$$A = \frac{n}{H}$$

Fulton's condition factor (K) relies on the assumption that fish weight is proportional to the cube of fish length. This index is widely used to estimate the general physiological state of fish, both at the individual and population levels. For each specimen, total length, standard length, and body mass were recorded. The calculation of the condition index relied on an allometric model in which the exponent b was treated as a constant, allowing comparisons of condition factor across different classes or groups of fish. Fulton's condition factor (K) was determined using the following formula:

$$K = \frac{W \cdot 100}{L^b}$$

where W = fish weight (g), L= standard length (cm), and b= allometric coefficient considered equal to 3 (Le Cren, 1951).

Fulton's condition factor was multiplied by 100 to bring values closer to 1.

A value near 1 indicates a normal state, values greater than 1 suggest that the fish is in good condition ("fat"), while values below 1 indicate poorer condition ("thin"). This morphometric index is based on the principle that, for a given length, a heavier fish is considered to be in better overall condition.

3.5 Statistical Analyses: In this study, three statistical tools were employed to evaluate the dynamics of parasitic infestation in *Chrysichthys nigrodigitatus*. The Chi-Square test (χ^2) was applied to assess the variability of infestation rates according to season, sex, and host size. For the comparison of parasitic intensities as well as condition factor (K) values among multiple groups, the non-parametric Kruskal–Wallis and Mann–Whitney tests were used. These tests are particularly suitable when distributions do not follow normality or when sample sizes are unequal. Differences in parasitic intensity between two distinct samples were specifically tested using the Mann–Whitney test, providing a robust comparison between two independent groups. All statistical analyses were conducted using STATISTICA software version 7.1, with the significance level set at $p < 0.05$. This conventional threshold allowed the determination of the statistical significance of observed variations and ensured the rigor of biological interpretations.

4 RESULTS

4.1 Inventory of gill parasitic Copepod species in *Chrysichthys nigrodigitatus*: Systematic examination of the gills of *Chrysichthys nigrodigitatus* revealed a total of 9.375 parasitic copepod individuals, collected from the two stations namely Adiaké and Aby village, located in Aby Lagoon. Based on standard morphological criteria, identification revealed the presence of three distinct gill parasitic copepod species namely *Ergasilus latus*, *Lernaea cyprinacea* and *Ergasilus sarsi* (Figure 2). These three species were observed simultaneously in each of the studied sampling sites, indicating a homogeneous distribution of parasitic copepods within the host populations.

Figure 2. Gill parasitic Copepod species of *Chrysichthys nigrodigitatus* in the Aby lagoon

(A) : *Ergasilus latus* ; (B) : Copepodite stage of *Lernaea cyprinacea* ; (C) : *Ergasilus sarsi*

4.2 Spatial pattterns of gill parasitic copepod in *Chrysichthys nigrodigitatus* from Aby lagoon: The comparative analysis of epidemiological indices of gill parasitic copepod in *Chrysichthys nigrodigitatus* from Aby Lagoon across the two stations is summarized in Table I. Results show that the prevalence of *Ergasilus latus* (69.91%), *E. sarsi* (43.32%) and *Lernaea cyprinacea* was higher in Aby village, although these values remain generally close to those observed at the Adiaké station., reflecting a marked spatial difference in the distribution of this species. Chi-Square tests indicated that prevalence differences between the two stations were not significant for *Ergasilus latus*, *E. sarsi* and *Lernaea cyprinacea* ($p > 0.05$). Mean intensity and abundance values of parasitic copepods also revealed contrasts between stations. Recorded mean intensities were 5.64 ± 0.7 for *E. latus*, 4.1 ± 0.3 for *E. sarsi*, and 5.41 ± 0.3 for *L. cyprinacea*, while corresponding abundances were 4.58, 1.84, and 3.79 individuals, respectively. Kruskal–

Wallis and Mann–Whitney tests applied to these data showed that fish from Aby village were significantly more infested by all three species than those from the Adiaké station ($p < 0.05$). Overall, across both sampling sites, *E. latus* and *L. cyprinacea* appeared as dominant species (prevalence > 50%), reflecting their strong infestation capacity and adaptation to local ecological conditions. Conversely, *E. sarsi* was classified as an intermediate species (prevalence values varied between 10% and 50%), suggesting lower competitiveness or a more restricted ecological niche.

Table 1 : Spatial distribution of gill parasitic Copepod in *Chrysichthys nigrodigitatus* from Aby lagoon

Sampling stations	Parasites species	Examined hosts	Infested hosts	P (%)	MI± SD	A
Adiaké	***Ergasilus latus***	**480**	**337**	**69.56**	**5.09±0.7**	**4,40**
	Ergasilus sarsi	**480**	**207**	**42.72**	**3.64±0.3**	**1.64**
	Lernaea cyprinacea	**480**	**298**	**61.57**	**5.1±0.5**	**3.26**
Aby village	***Ergasilus latus***	**472**	**331**	**69.91**	**5.64±0.2**	**4.58**
	Ergasilus sarsi	**472**	**205**	**43.32**	**4.10±0.1**	**1.84**
	Lernaea cyprinacea	**472**	**318**	**66.96**	**5.41±0.3**	**3.79**

MI±SD : Mean intensity± Standard deviation ; P : Prevalence ; A : Abundance

4.3 Temporal trends in gill parasitic Copepod prevalence and parasitic intensity in *Chrysichthys nigrodigitatus*: Figures 3, 4 and 5 illustrate the monthly fluctuations of epidemiological indices for the three copepod species recorded in *Chrysichthys nigrodigitatus* from Aby Lagoon. In Adiaké station results showed that the highest prevalence values were recorded in octobre, corresponding to the long rainy season, with 79.55% for *Ergasilus latus*, 69.77% for *Lernaea cyprinacea*, and 48.84% for *E. sarsi*. Conversely, the lowest values were observed in September for *E. latus* (59.46%), in September and February for *L. cyprinacea* (51.35%) and in January for *E. sarsi* (34.29%), periods corresponding to the long dry season. The Chi-Square test revealed significant differences in prevalence between seasons ($p < 0.05$). Regarding mean parasitic intensity, maximum values were recorded in July, during the short rainy season, with 8.94 ±1.3 for *E. latus*, 7.81 ±1.2 for *L. cyprinacea* and 5.64 ± 0.6 for *E. sarsi*. The lowest intensities were observed in March, during the long dry season, with 3.42 ± 2.18 and 1.29 ±0.4, respectively. Parasitic abundance followed a similar trend, with maximum values in July (7 for *E. latus* and 5.26 for *L. cyprinacea*) and in May for *E. sarsi* (7.96). The Mann–Whitney test confirmed that parasitic intensities varied significantly across seasons ($p < 0.05$). At Aby village station monthly data also revealed marked seasonal fluctuations. Maximum prevalence values were observed in April for *E. latus* (79.49%), in October for *E. sarsi* (48.78%), and in October for *L. cyprinacea* (78.05%), all corresponding to the rainy season. The Chi-Square test highlighted significant differences between seasons ($p < 0.05$). The highest mean parasitic intensities were recorded in October for *E. latus* (8.84 ±1.3), in June for *E. sarsi* (5.95 ±0.3), and in June for *L. cyprinacea* (7.71 ±1.2), confirming strong infestations during rainy periods. Maximum parasitic abundances were obtained in October for *E. latus* (6.90), in May for *E. sarsi* (2.80), and in June for *L. cyprinacea* (6.0). The Mann–Whitney test showed that parasitic intensities varied significantly across seasons ($p < 0.05$).

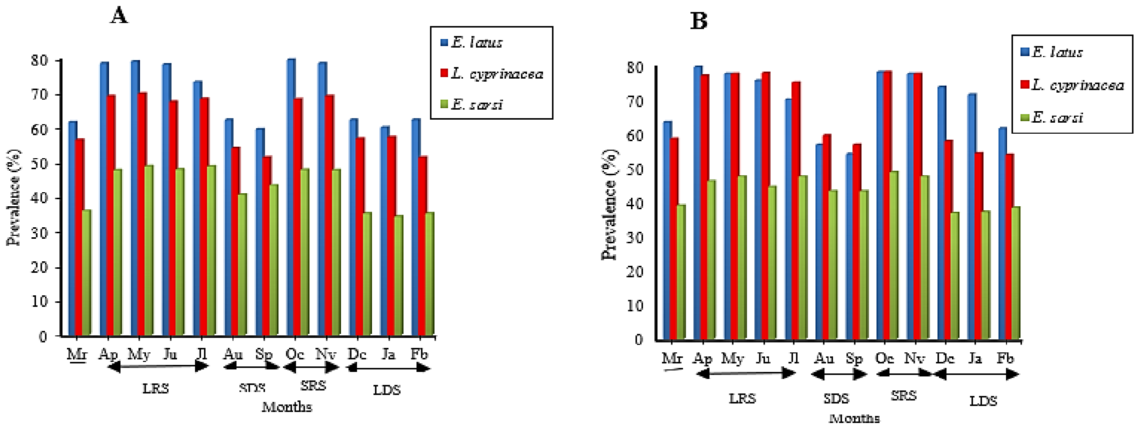

Figure 3. Variation in the prevalence of gill Copepod parasitic of *Chrysichthys nigrodigitatus* according to the seasons at different stations. (A) : Adiaké ; (B) : Aby village ; *E.* : *Ergasilus* ; *L.* : *Lernaea* ; LRS : Long Rainy Season ; SRD : Short Rainy ; SDS ; Short Dry Season ; LDS : Long Dry Season ; Ja : January ; Fb : February ; Mr : March ; Ap : April ; My : May ; Ju : June ; Jl : July ; Au : August ; Sp : September ; Oc : October ; Nv : November ; Dc : December

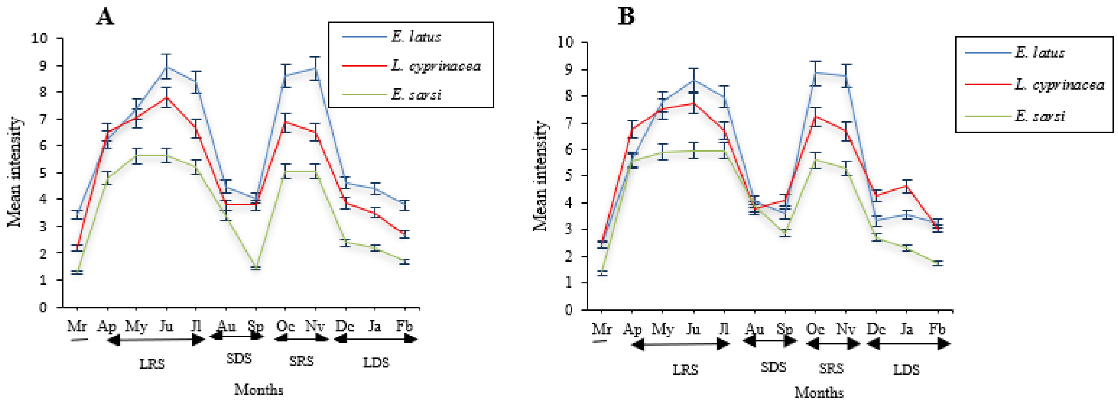

Figure 4. Variation in the mean intensity of gill Copepod parasitic of *Chrysichthys nigrodigitatus* according to the seasons at different stations. (A) : Adiaké ; (B) : Aby village ; *E.* : *Ergasilus* ; *L.* : *Lernaea* ; LRS : Long Rainy Season ; SRD : Short Rainy ; SDS ; Short Dry Season ; LDS : Long Dry Season ; Ja : January ; Fb : February ; Mr : March ; Ap : April ; My : May ; Ju : June ; Jl : July ; Au : August ; Sp : September ; Oc : October ; Nv : November ; Dc : December

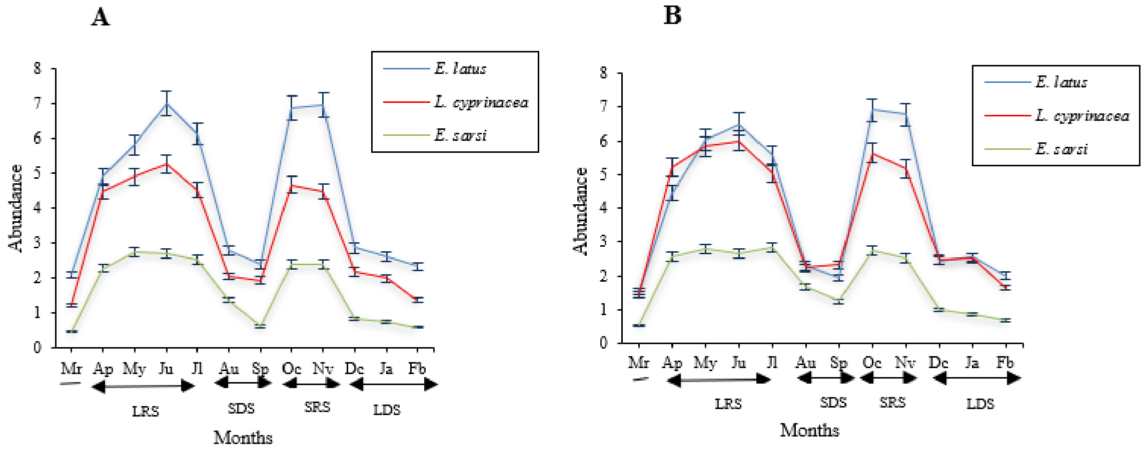

Figure 5. Variation in the abundance of gill Copepod parasitic of *Chrysichthys nigrodigitatus* according to the seasons at different stations. (A) : Adiaké ; (B) : Aby village ; *E.* : *Ergasilus* ; *L.* : *Lernaea* ; LRS : Long Rainy Season ; SRD : Short Rainy ; SDS ; Short Dry Season ; LDS : Long Dry Season ; Ja : January ; Fb : February ; Mr : March ; Ap : April ; My : May ; Ju : June ; Jl : July ; Au : August ; Sp : September ; Oc : October ; Nv : November ; Dc : December

4.4 Parasitic infestation of *Chrysichthys nigrodigitatus* according to host sex: A total of 952 individuals of *Chrysichthys nigrodigitatus* were examined, comprising 487 males and 465 females. Parasitic indices by sex are presented in Tables 2 and 3. At the Adiaké sampling site results showed that the highest prevalence values were recorded in males for *Ergasilus latus* (80.16%) and *Lernaea cyprinacea* (77.73%). In contrast, *Ergasilus sarsi* exhibited a higher prevalence in females (64.81%). Regarding mean parasitic intensity, the strongest values were observed in males for *E. latus* (7.98±1.2) and *L. cyprinacea* (6.37±0.8), whereas females displayed higher intensity for E. sarsi (4.54±0.1). The Mann–Whitney test revealed significant differences ($p < 0.05$), indicating that males harbored more *E. latus* and *L. cyprinacea*, while females were more infested by *E. sarsi*. In the Aby village station a similar trend was observed. Males exhibited the highest prevalence and mean parasitic intensity for *E. latus* (81.92%; 7.62 ±1.2) and *L. cyprinacea* (81.66%; 6.97 ±1.3). Conversely, females showed higher prevalence for E. sarsi (61.63%) with a mean intensity of 5.26±0.4. Statistical tests (Chi-Square and Mann–Whitney) confirmed significant differences between sexes for all parasitic indices ($p < 0.05$).

Table 2 : Sex-related variation of epidemiological parameters of gill parasitic Copepod in *Chrysichthys nigrodigitatus* from Aby lagoon at Adiaké

	Male (n=247)			Female (n=233)		
Parasitic species	Infested fish	P(%)	MI±SD	Infested fish	P(%)	MI±SD
Ergasilus latus	198	80.16	7.98±1.2	139	59.66	4.33±0.3
Lernaea cyprinacea	192	77.73	6.37±0.8	106	45.49	3.75±0.2
Ergasilus sarsi	56	22.67	2.34±0.1	151	64.81	4.54±0.1

MI±SD : Mean intensity± Standard deviation ; P : Prevalence

Table 3 : Sex-related variation of epidemiological parameters of gill parasitic Copepod in *Chrysichthys nigrodigitatus* from Aby lagoon at Aby village

	Mâles (n=240)			Femelles (n=232)		
Parasitic species	Infested fish	P(%)	MI±SD	Infested fish	P(%)	MI±SD
Ergasilus latus	199	82.92	7.62±1.2	132	56.89	3.37±0.2
Lernaea cyprinacea	196	81.66	6.97±1.3	122	52.58	3.69±0.1
Ergasilus sarsi	62	25.83	2.06±0.3	143	61.63	5.26±0.4

MI±SD : Mean intensity± Standard deviation ; P : Prevalence

4.5 Variation in the condition factor of *Chrysichthys nigrodigitatus* infested and uninfested by gill parasitic Copepod in Aby Lagoon: The condition factor values for both Cnigro specimens infested and uninfested by gill copepod parasites varied according to the sampling sites within the Aby lagoon (Table 4). At Aby village station, the mean condition factor of infested individuals was 0.31 ± 0.01, compared to 0.74 ± 0.03 in uninfested fish. Similarly, in the Adiaké station, values were 0.43 ± 0.01 for parasitized individuals and 0.81 ± 0.02 for non-parasitized (uninfested) ones. In both studied stations, parasitized fish exhibited significantly lower values compared to uninfested individuals (Mann–Whitney U, $p < 0.05$). Analyses revealed a clear difference in the condition factor between *Chrysichthys nigrodigitatus* individuals infested with gill copepods and those free of infestation.

Table 4 : Condition factor of *Chrysichthys nigrodigitatus* infested and uninfested by gill parasitic Copepod in Aby lagoon

Sampling stations	Hosts	Number	Condition factor (g/cm³)	p-value
Aby Village	Examined	472		0.01
	Infested	369	0.31±0.01	
	Uninfested	103	0.74±0.03	
Adiaké	Examined	480		0.02
	Infested	392	0.43±0.01	
	Uninfested	88	0.81±0.02	

5 DISCUSSION

The study revealed the presence of three gill parasitic copepod species namely *Ergasilus latus*, *Lernaea cyprinacea* and *Ergasilus sarsi*. This specific diversity illustrates a parasitic community characteristic of tropical aquatic environments, where the coexistence of several copepod species is a common phenomenon. The dominance of *E. latus* may be explained by its remarkable ecological plasticity, enabling it to colonize a wide range of hosts and extend across a broad geographical area. This adaptive capacity provides the species with a competitive advantage in environments subject to significant abiotic variations. The simultaneous presence of these three species reflects a complex ecological structure, in which each parasite occupies a particular niche, thereby reducing interspecific competition (Williams and Jones, 1994). Such niche partitioning may manifest through differentiated preferences for attachment sites on the host (gills, skin, buccal cavity), targeted developmental stages, or distinct reproductive strategies. This organization promotes the stability of the parasitic community and reflects a dynamic balance between host exploitation and the maintenance of parasitic diversity. Furthermore, the observed co-infestation may result from favorable environmental conditions, such as high temperatures and optimal salinity, which directly influence the survival, fecundity, and transmission of parasitic copepods (Timi and Poulin, 2020). These abiotic parameters, combined with host population density, create a context conducive to parasitic proliferation. In tropical systems, where seasonal variations are often pronounced, these factors may intensify infestation cycles and favor the persistence of parasites over time. Finally, the concurrent presence of *E. latus*, *L. cyprinacea*, and *E. sarsi* may also be interpreted as an indicator of the ecological health of the aquatic environment. High parasitic diversity is often correlated with host richness and elevated trophic complexity. However, in the context of fisheries management, such diversity may represent a threat to fish populations due to the cumulative effects of multiple infestations on host physiology and survival. The spatial differences in Chrysichthys nigrodigitatus infestation observed in this study can be interpreted in light of the ecological characteristics of each station. The Aby village station, characterized by traditional aquaculture practices and the accumulation of organic matter from local activities (acadja culture), appears to favor the development of parasitic copepods. Moreover, L. cyprinacea is known for its ability to exploit environments rich in plant debris and nutrients. Conversely, the Adiaké station—more urbanized and subject to strong anthropogenic disturbance, which creates environmental instability (fluctuations in salinity, temperature, and oxygen) and reduces host fish abundance—may provide less favorable conditions for the proliferation of these parasitic species. Thus, the spatial distribution of branchial copepods in Aby

Lagoon reflects not only the specific ecological preferences of each species but also the influence of local anthropogenic and environmental factors. This spatial heterogeneity underscores the importance of accounting for habitat-specific characteristics when assessing parasitic risk and designing appropriate fisheries management strategies.Temporal variations in the prevalence and mean intensity of parasitic infestations by Copepods, with maximum values observed during the rainy season, reflect a pronounced seasonal dynamic typical of tropical ecosystems. This trend results from a complex interaction between abiotic and biotic factors. Environmental parameters such as temperature, salinity, humidity, and organic load play a decisive role in the proliferation and survival of infectious stages (Marcogliese, 2004; Akoll *et al.* 2012). During the rainy season, increased biological activity and greater availability of intermediate hosts promote parasite transmission. Reduced salinity and higher water turbidity create favorable conditions for the dispersal of infective larvae, thereby intensifying infestation cycles. Similar observations were reported by Ali and Al-Hyali (2018), confirming that periods of heavy rainfall constitute ecological windows conducive to the spread of parasitic copepods. At the study site, the practice of "acadja-culture," based on the installation of submerged vegetative structures, contributes not only to fish reproduction but also to the accumulation of organic matter. The build-up of dead wood and leaves creates nutrient-rich microhabitats that support the development and survival of infective stages. These structures act as biological concentration zones, increasing opportunities for contact between parasites and fish, consistent with the findings of Lafferty and Kuris (1999). Furthermore, the high infestation rates observed during the rainy season may also be attributed to contamination of the aquatic environment by domestic effluents and agricultural runoff, including pesticides. Such anthropogenic inputs degrade water quality and weaken the immune defenses of aquatic organisms, making them more susceptible to parasitic infestations. In contrast, the dry season is characterized by a significant reduction in infestations. This decline is linked to decreased metabolic activity of aquatic organisms, limited water mixing, and reduced biological productivity, resulting in lower availability of infectious stages (Möller and Anders, 1986). The scarcity of intermediate hosts during this period further restricts transmission opportunities, contributing to an attenuated parasitic dynamic. Moreover, increased temperature, salinity, and conductivity during the dry season lead to higher mortality of adult worms, thereby reducing parasitic pressure (Modu *et al.* 2014; Adou *et al.* 2021 ; Adou *et al.* 2025). The analysis revealed that in Aby Lagoon, the copepods *Ergasilus latus* and *Lernaea cyprinacea* exhibit higher prevalence in male individuals of *Chrysichthys nigrodigitatus*. This pattern may be attributed to the more active and exploratory behavior of males, which increases their exposure to infested areas. While foraging, fish explore diverse aquatic habitats, thereby enhancing their risk of contamination. In addition, males often display territorial or reproductive behaviors, greater mobility, and aggressive interactions, all of which may elevate their likelihood of encountering infective stages present in the environment, as previously noted by Moore and Wilson (2002). Furthermore, testosterone levels, which are higher in males, are known for their immunosuppressive effects, reducing their ability to resist parasitic infections (Leung and Koprivnikar, 2016; Poulin, 2006). Conversely, female hosts showed a greater affinity for the copepod *Ergasilus sarsi*. This may be explained by the presence of estrogens, which enhance immunity in females. These findings are consistent with Boucenna *et al.* (2018), who reported stronger infestations in male individuals by Copepods in a similar environment. Females, however, tend to adopt more sedentary or conservative behaviors, which may limit their exposure. The lower infestation rates observed in female fish could also be linked to energy allocation strategies primarily directed toward reproduction, potentially weakening their immune system and increasing susceptibility to parasitic infections. Additionally, specific feeding habits or occupation of habitats more favorable to infective stages may reinforce this trend. Berrouk *et al.* (2018) observed a similar trend in Carassius carassius at the Beni Haroun Dam (Algeria), with females displaying higher parasite abundance and intensity indices than males. In this study, the condition factor, used as an indicator of the general health and physiological status of fish, was found to be significantly lower in individuals infested by the three species of parasitic copepods. This parameter, typically calculated from the length–weight relationship (Fulton's condition factor), is a reliable tool for assessing energy reserves and overall body condition in fish. A reduced condition factor in parasitized individuals reflects an alteration of their physiological state, often associated with a combination of nutritional, metabolic, and immune stress. These results can be explained by the fact that parasitic copepods, by attaching to the gills or skin, cause mechanical lesions and directly extract nutrients from the host. Such damage compromises vital functions including respiration, osmoregulation, and metabolism, leading to decreased physiological efficiency and increased vulnerability to other environmental stressors (Marcogliese, 2004). Moreover, the activation of the immune response against parasitic infection requires considerable energy investment, diverting resources normally allocated to somatic growth and reproduction (Dautremepuits *et al.* 2006). This redistribution of energy results in reduced biological performance, notably slower growth, decreased fecundity, and increased mortality. The findings thus highlight the deleterious impact of parasitism on fish condition and survival, confirming that copepod infestations represent a major constraint for fish populations. Beyond the individual level, these physiological alterations may have repercussions at the population and ecosystem scales. A generalized decline in condition factor can affect fish population dynamics, reduce their competitiveness within trophic networks, and compromise the resilience of aquatic ecosystems. Similar results were obtained by Omeji *et al.* (2022) in Synodontis euptera and Auchenoglanis occidentalis from Benue river in Nigeria, where males fish exhibited lowest condition factor values compared to females ones

6 CONCLUSION

This study highlighted the presence of three gill-infesting copepod species in *Chrysichthys nigrodigitatus*, namely *Ergasilus latus*, *E. sarsi*, and *Lernaea cyprinacea*. The results revealed heavy infestations during the rainy season, along with significant variation according to host sex, reflecting the combined influence of environmental and biological factors on parasite dynamics. The negative impact of parasitism on fish health was clearly demonstrated by the reduction in condition factor, a reliable indicator of the physiological and energetic status of infested individuals. These observations emphasize the ecological importance of parasitic copepods in tropical freshwater ecosystems, where they play a non-negligible role in regulating host populations and structuring aquatic communities. They also highlight the need for continuous monitoring of fish health, both in natural environments and aquaculture systems, to prevent ecological and economic consequences associated with parasitic infestations. Furthermore, this research provides a solid foundation for future investigations into host–parasite interactions in tropical settings. It opens perspectives for studying parasite adaptation mechanisms, host immune responses, and the influence of climatic variability on infestation dynamics. In the context of environmental change and intensifying human activities, understanding these interactions is essential for the sustainable management of fisheries resources and the preservation of aquatic biodiversity.

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