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Dynamic of Nematode parasite populations in Catfish *Clarias anguillaris* (Clariidae) from N'Denou-Bandama river, Côte d'Ivoire

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ABSTRACT

Objective: The African catfish *Clarias anguillaris* is a strategic species for aquaculture due to its rapid growth, tolerance to harsh environmental conditions, and socio-economic importance in food security. However, its performance can be affected by Nematode parasite infestations. In the Bandama River at N'Denou, where water quality is severely degraded by anthropogenic activities, no parasitological study had previously been conducted. The objective of this study was to inventory the Nematode parasites of *C. anguillaris*, identify their attachment sites, and assess the influence of season and host sex on infestation levels.

Methodology and Results: From April 2024 to March 2025, a total of 560 specimens were collected using gill nets. Parasites were identified following standard procedures, and statistical analyses (Chi-square (X^2), Mann-Whitney (U) and Kruskal-Wallis (K) tests) were performed to compare infestation levels. Nine (9) Nematode species were recorded : *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Contracaecum sp*., *Falcaustra petrei*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, and *Anisakis sp*. The highest prevalence (P) and mean intensity (MI) values were observed in the intestine, particularly for *P. cyathopharynx* (P = 78.04% ; MI = 16.17±1.02) and *P. laeviconchus* (P = 74.11% ; MI = 14.25±1.01). During the dry season, maximum values were recorded for *P. cyathopharynx* (P = 97.92% ; MI = 23.32± 2.2), *P. laeviconchus* (P = 91.84% ; MI = 23.38±2.1), and *F. petrei* (P = 85.11% ; MI = 19.39±1.7). Females were generally more heavily infested, whereas certain species were more prevalent in males.

Conclusion and Application of results: These findings provide a scientific basis for implementing seasonal parasite monitoring programs, improving water quality management, and adopting prophylactic measures in aquaculture, thereby contributing to the sustainable management of the species.

Keywords : *Clarias anguillaris*, Nematode, Parasite, Infestation, Bandama river, Côte d'Ivoire

INTRODUCTION

The African catfish *Clarias anguillaris* is an essential resource for both capture fisheries and aquaculture in sub-Saharan Africa. It therefore represents a major fishery and aquaculture resource, contributing significantly to food security and local livelihoods (Adande *et al*., 2015). Owing to its robustness, its ability to reproduce in captivity, its adaptation to oxygen-poor environments, and its facultative aerial respiration, *Clarias anguillaris* is widely used in fish farms (Legendre *et al*., 1992). Its farming and commercialization, which generate substantial income for many rural communities, are also considered a means of reducing poverty and creating employment opportunities (Adande *et al*., 2015). Despite its high nutritional and economic value, *Clarias anguillaris* remains vulnerable to various natural stressors, particularly infestations caused by parasitic Nematodes. These parasites severely compromise fish health by inducing tissue damage, inflammation, and anemia, thereby disrupting essential physiological functions (Bichi et Yelwa, 2010 ; Dezfuli *et al*., 2011). Their presence leads to reduced growth, weight loss, and a decline in condition factor (Britton *et al*., 2011 ; Scholz *et al*., 2012). Infestations also impair reproductive efficiency and increase susceptibility to secondary infections (Truter *et al*., 2023). Ultimately, they undermine population resilience and aquaculture productivity. In humans, certain zoonotic species can be transmitted through the consumption of infected fish, causing parasitic diseases (Dorny *et al*., 2009 ; Bouchriti *et al*., 2014). This study is therefore crucial for preventing health risks, improving fisheries management, and strengthening food security. Research on Nematodes affecting *Clarias anguillaris* is extensive, providing essential data for understanding host-parasite interactions in this species (Sinaré *et al* 2021 ; Sissoko *et al*., 2021). In Côte d'Ivoire, research on Nematode parasites of fish remains very limited and is restricted to the work of Blahoua *et al.* (2025) on *Oreochromis niloticus* from Lake Ayamé 1. To date, no study has been conducted on *Clarias anguillaris* in the Bandama River at N'Denou, hence the need for and relevance of the present study. However, this species represents a key economic resource for local populations along the Bandama River at N'Denou, due to its high market value and its central role in food security and the livelihoods of riparian communities. Any deterioration in its health status is therefore likely to have direct repercussions on fishers' incomes as well as on the supply of animal protein to local populations. Furthermore, this section of the river is highly exposed to various sources of pollution, particularly those arising from illegal artisanal gold mining and intensive agricultural activities. These practices lead to the introduction of contaminants such as heavy metals, hydrocarbons, pesticides, and fertilizers into the aquatic environment, thereby altering the physicochemical characteristics of the water. Such environmental changes may disrupt ecological balance and weaken the immune defenses of fish, making them more vulnerable to parasitic infestations. These environmental disturbances are likely to promote the proliferation of Nematode parasites by influencing both their life cycles and the availability of their intermediate hosts. Consequently, they may lead to an increase in both the prevalence and intensity of infestations, with harmful effects on fish health. In addition, fish stocks, once abundant, have gradually declined to alarming levels. This decline may result from a combination of factors, including overexploitation, habitat degradation, and increased parasitic pressure. In this context, the lack of scientific data on Nematode parasites in *Clarias anguillaris* in this area represents a significant knowledge gap, thereby fully justifying the need for the present study. The objective of this study is to identify and characterize nematode parasites infecting *Clarias anguillaris* in the Bandama River at N'Denou, in order to understand the parasite dynamics within this ecosystem.

MATERIAL AND METHODS

Study area: The Bandama river, located entirely within Côte d'Ivoire, extends for approximately 1050 km and drains a watershed of 97,500 km², between 3°50'-7°00' W and 5°00'-10°20' N **(**Figure 1**)**. It originates in the north, between Korhogo and Boundiali, and flows into the Grand-Lahou lagoon before reaching the Atlantic Ocean. Along its course, the river traverses several climatic zones, imparting contrasting ecological and hydrological characteristics to the basin (Koné, 2002). Its hydrological regime is characterized by marked seasonal variability, alternating between two rainy seasons (March-June and September-October) and two dry seasons (July-August and November-February) (Brou, 2005). The river plays a major role in agriculture, fisheries, and hydroelectric production, notably through the Kossou dam, a cornerstone of the country's energy supply (Touré, 2015). The present study was conducted in the locality of N'Denou, situated in the southern section of the river, upstream of the Singrobo-Ahouaty dam (4°59'-5°00' W ; 6°10'-6°11' N). The sampling station was selected due to its high level of anthropogenic disturbance. It is directly influenced by agricultural activities, with riverbanks occupied by food crops (maize, eggplant) and a substrate composed mainly of sand, interspersed with mud, clayey and silty zones, as well as various rocky formations. Aquatic vegetation is dense, dominated by water hyacinths covering about 10% of the surface. The site is also subject to pressures from illegal artisanal gold mining. Additional disturbances include the presence of dead wood and leaves in the water, nearby cattle farming, and domestic activities such as laundry and dishwashing carried out directly in the river. These factors result in increased turbidity, higher sedimentation, and significant substrate modification. The surrounding forest cover, consisting of secondary forests, oil palms, rubber trees, and cocoa plantations, represents about 15%. The study area has an estimated average depth of approximately 7 meters.

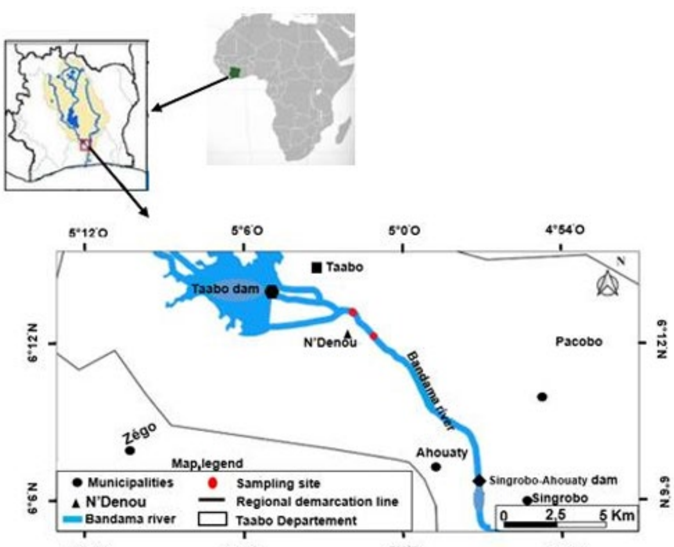

Figure 1 : Geographical location of Bandama River at the N'Denou sampling station

Fish sampling: Sampling was conducted from April 2024 to March 2025 in the Bandama River at N'Denou. A total of 560 specimens of *Clarias anguillaris* were captured using experimental and artisanal fishing techniques, representative of local practices. The collected individuals were immediately transported to the laboratory for examination. The taxonomic identification of the specimens was carried out using the dichotomous keys of Paugy *et al*. (2003), ensuring accurate species determination. The sex of the individuals was determined by direct observation of the gonads after dissection, which reliably distinguished males from females.

Parasitological analysis: Specimens of *Clarias anguillaris* were carefully dissected to expose the entire digestive tract. The tract was then meticulously removed and subdivided into distinct anatomical segments : the gills, oesophagus, stomach, intestine, general cavity, and gonads. Each segment was placed separately in Petri dishes containing 0.9% physiological saline solution, in accordance with the methodology described by Sadauki *et al*. (2022). To facilitate parasite detection, the sections were incised longitudinally and examined under a stereoscopic microscope at magnifications ranging from 10x to 30x. This procedure enabled direct observation of helminth emergence, particularly through the characteristic twitching movements they produced in the saline medium. The parasites detected were subsequently classified into different groups based on distinctive morphological criteria. The identification of Nematodes was carried out using the classical taxonomic references of Yamaguti (1961), Kabré (1997), and Gibbons (2010), which are recognized as authoritative works in fish parasitology. Following identification, the helminths were counted to assess their abundance and distribution across the various segments of the digestive tract. The specimens were then fixed in 5% formalin to preserve their morphology. Finally, for long-term conservation and to allow further analyses, they were transferred into 70% ethanol.

Epidemiological approach: The evaluation of parasitic infestation in *Clarias anguillaris* was carried out using parasite prevalence, calculated according to the formulas proposed by Bush *et al*. (1997). Prevalence refers to the proportion of hosts infected with a particular parasitic species

$$P = \frac{N}{H} x\,100$$

N= Number of infested hosts
N= total number of fish examined

To interpret the ecological role and distribution of parasitic species, the classification criteria proposed by Valtonen *et al.* (1997) were used to categorize parasite species based on their occurrence frequency and their relative contribution to the overall parasite community. Accordingly, nematode species were classified into three distinct categories

Principal or frequent species : those with a prevalence greater than 50%, indicating a dominant role in the host's parasitic structure,

Intermediate or secondary species : those with a prevalence between 10% and 50%, playing a moderate but significant role in the parasitic ecosystem.

Satellite or rare species : those with a prevalence below 10%, occurring sporadically and having a limited impact on the parasite community.

This classification makes it possible to understand not only the dynamics of parasitic populations but also their relative importance in the host's ecology and in host-parasite interactions within the Bandama River.

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

n = The total count of individuals belonging to a particular parasite species within the examined host sample

N = The total number of fish infected with the parasite in a sample

Statistical analysis: For the analysis of the data collected in this study, several statistical tests were employed to ensure robust interpretation of the results. The Chi-square (χ^2) test, the Mann-Whitney (U) test and the Kruskal-Wallis (K) test were applied depending on the type and distribution of the variables. These tests were used to evaluate the proportions and variations in parasitic infestation with respect to attachment sites, seasonal changes, and the sex of the fish. The Chi-square test allowed for the comparison of categorical variables, particularly the distribution of parasite prevalence across different groups. The Mann-Whitney (U) test was applied to assess differences between two independent groups when the data did not meet the assumptions of parametric tests, while the Kruskal-Wallis (U) test extended this comparison to more than two groups. All statistical analyses were performed using the software STATISTICA 7.1, with a significance threshold set at 5% ($p < 0.05$). This methodological framework ensured that the observed differences were not due to random variation, thereby strengthening the reliability of the ecological interpretations drawn from the parasitological data.

RESULTS

Species composition: The parasitological study of 560 *Clarias anguillaris* specimens identified nine Nematode species : *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Contracaecum sp.*, *Falcaustra petrei*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, *Camallanus polypteri* and *Anisakis sp*. These parasites were detected on all examined organs, with the highest abundance observed in the intestine (37%), stomach (22%) and cavity (20%) (Figure 2). A statistically significant difference was observed among the proportions of the different organs (Chi-square (χ^2) test ; $p < 0.05$).

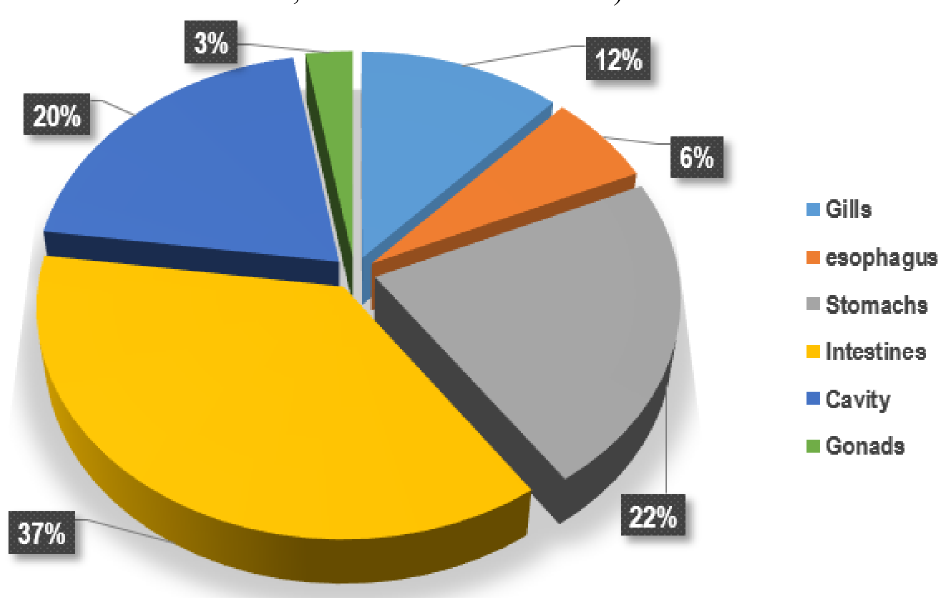

Figure 2 : Proportions of Nematode Parasites in *Clarias anguillaris* Organs

Prevalence and mean intensity of parasitic Nematodes according to attachment organs in *Clarias anguillaris:* The prevalence and mean intensity values of Nematode parasites according to attachment organs in *Clarias anguillaris* are presented in figure 3. The analysis has shown that *Paracamallanus cyathopharynx* reached a maximum prevalence of 78.04% in the intestine. followed by the stomach (69.11%), the body cavity (60%) and the gills (58.75%) (Figure 3A). The Chi-square (χ^2) test revealed a significantly uneven distribution of this species among the organs, with the intestine appearing as the preferred site ($p < 0.05$). In *Procamallanus laeviconchus*, the highest prevalence was observed in the intestine (74.11%), followed by the stomach (64.82%), the body cavity (59.64%), the esophagus (56.07%) and the gills (35.71%). The statistical test confirmed a differential distribution of this Nematode across host organs (Chi-square (χ^2) test ; $p < 0.05$). For *Brevimulticaecum heterotis*, the intestine constituted the main site of infestation (29.46%), followed by the stomach (23.75%), whereas no infestation was recorded in the other organs. The Chi-square (X^2) test highlighted an organ-specific distribution ($p < 0.05$). *Falcaustra petrei* showed maximum prevalence in the intestine (66.43%), followed by the body cavity (60.54%) and the gonads (23.93%). The statistical analysis demonstrated significant differences in parasite prevalence across the examined organs (Chi-square (χ^2) test ; $p < 0.05$). The prevalence of *Rhabdochona congolensis* also varied among organs : 35.18% in the intestine, 26.96% in the stomach, 23.57% in the oesophagus and 3.57% in the gonads. The Chi-square (χ^2) test indicated a significantly heterogeneous distribution ($p < 0.05$). In *Camallanus polypteri*, prevalence was higher in the stomach (27.5%) than in the intestine (3.75%). The Chi-square (χ^2) test indicated a significantly heterogeneous distribution in prevalence among organs ($p < 0.05$). *Spirocamallanus spiralis* was predominantly found in the intestine (35.89%), followed by the body cavity (3.21%). The Chi-square (X^2) test confirmed significant variation in prevalence among organs ($p < 0.05$). The distribution of *Contracaecum sp*. showed decreasing prevalence from the intestine (34.11%) to the body cavity (29.46%) and the stomach (3.93%). The Chi-square (χ^2) test indicated a significant organ-specific infestation ($p < 0.05$). Finally, *Anisakis sp*. exhibited maximum prevalence in the body cavity (26.79%), followed by the intestine (23.92%) and the stomach (3.04%). The Chi-square (χ^2) test revealed a significantly differentiated distribution among the host organs ($p < 0.05$). The mean intensities of Nematode parasites according to attachment sites in *Clarias anguillaris* are presented in Figure 3B. Examination showed that *Paracamallanus cyathopharynx* exhibited the highest mean intensity values in the stomach (16.17 ±1.02), followed by the intestine (15.81 ± 0.9), the body cavity (11.84 ± 0.6), and the gills (10.67 ±0.3The Kruskal-Wallis (K) test revealed a significantly uneven distribution of this parasite, with the intestine appearing as the most heavily parasitized organ ($p < 0.05$). Similarly, *Procamallanus laeviconchus* recorded its highest mean intensities in the intestine (14.25 ±1.01), followed by the gills (13.46 ±0.4), the stomach (13.28 ±1.02), the body cavity (11.72 ±0.2) and the oesophagus (10.17 ± 1.5). Statistical analysis indicated a differential infestation across organs (Kruskal-Wallis (K) test ; $p < 0.05$). In *Brevimulticaecum heterotis*, the highest mean intensity was observed in the stomach (11.64 ±1.3), followed by the intestine (10.98 ±1.1), whereas no infestation was recorded in the other organs. The Kruskal-Wallis (K) test highlighted a strictly organ-specific distribution ($p < 0.05$). For *Falcaustra petrei*, the maximum mean intensity was recorded in the gonads (13.87 ±0.1), followed by the intestine (13.62 ±0.6), the body cavity (11.19 ±0.4), and the gills

(10.65 ±0.2). A significant difference was observed in mean parasite intensity among organs (Kruskal-Wallis (K) test ; $p < 0.05$). The mean intensity of *Rhabdochona congolensis* also varied among organs, with values of 11.11 ±0.5 in the oesophagus, 10.95 ± 0.6 in the stomach, 9.55 ± 0.1 in the intestine and 4.4 ± 0.1 in the gonads. The Kruskal-Wallis (K) test revealed a significantly heterogeneous distribution ($p < 0.05$). In *Camallanus polypteri*, the mean intensity was higher in the stomach (10.39 ± 1.1) than in the intestine (3.81 ± 0.2), with a statistically significant difference (Kruskal-Wallis (K) test ; $p < 0.05$). *Spirocamallanus spiralis* was mainly localized in the intestine (10.53±0.3) and the body cavity (2.72 ± 0.1). Statistical analysis revealed a significant variation in mean intensity among organs (Kruskal-Wallis (K) test ; $p < 0.05$). The distribution of *Contracaecum sp*. showed decreasing mean intensity from the body cavity (8.91 ±0.1) to the intestine (8.90 ±0.3) and the stomach (3.86 ±0.2). The Kruskal-Wallis (K) test highlighted a significant difference in prevalence among organs ($p < 0.05$). Finally, *Anisakis sp*. showed its highest mean intensities in the intestine (9.80 ± 0.6), followed by the body cavity (9.22 ±0.6) and the stomach (4.18 ±0.2). The statistical test revealed a significantly differentiated distribution among host organs (Kruskal-Wallis (K) test ; $p < 0.05$).

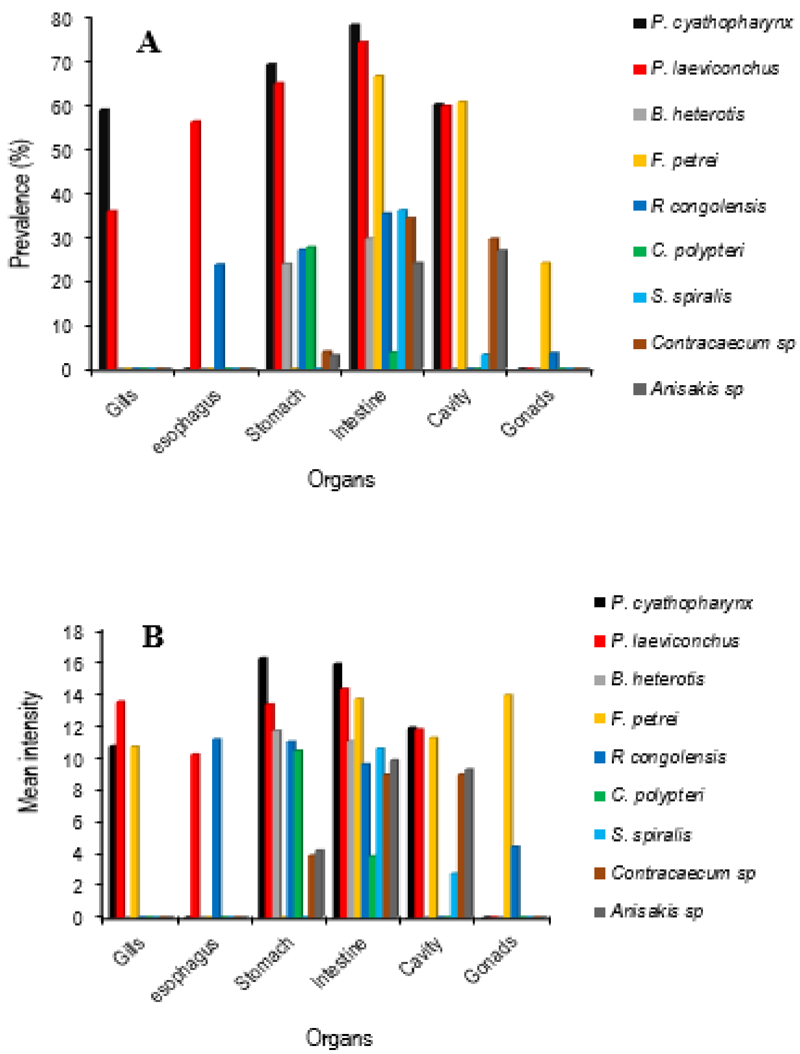

Figure 3 : Prevalence (A) and Mean intensity (B) of Nematode species according to attachment organs in *Clarias anguillaris P= Paracamallanus cyathopharynx, P= Procamallanus laeviconchus, R= Rhabdochona congolensis, S= Spirocamallanus spirale, B = Brevimulticaecum heterotis, C= Camallanus polypteri, Anisakis sp., F= Falcaustra petrei et Contracaecum sp*

Parasitism of *Clarias anguillaris* according to host sex

Gill infestation: Gill infestation of *Clarias anguillaris* according to host sex (Figure 4A) revealed that among males, 86.93%, 57.24% and 13.07% were infected with *P. cyathopharynx*, *P. laeviconchus* and *F. petrei*, respectively. In females, the corresponding prevalence rates were 29.96%, 13.72% and 59.57%. The Chi-square (χ^2) test indicated a significant difference in prevalence between male and female fish ($p < 0.05$). Thus, males were predominantly parasitized by *P. cyathopharynx* and *P. laeviconchus*, whereas females mainly harboured *F. petrei*. Regarding mean intensity, males exhibited higher values for *P. cyathopharynx* (12.04 ±0.7) and *P. laeviconchus* (14.83 ±1.3), while *F. petrei* showed lower values (5.65 ±0.4). In females, mean intensities were 6.61 ± 0.1 for *P.*

cyathopharynx, 7.60 ± 0.6 for *P. laeviconchus* and markedly higher for *F. petrei* (12.02 ± 0.7) (Figure 4B). The Mann-Whitney (U) test confirmed that males were significantly parasitized by *P. cyathopharynx* and *P. laeviconchus*, whereas females harboured significantly higher parasite loads of *F. petrei* ($p < 0.05$).

Oesophageal infestation: Maximum prevalence values were observed in males, with 75% for *P. cyathopharynx* and 37.81% for *R. congolensis*. In contrast, females showed lower prevalence rates of 36.46% and 9.02%, respectively (Figure 4A). The chi-square (χ^2) test showed that these differences in prevalence between male and female fish were statistically significant, with males being more heavily parasitized than females ($p < 0.05$). Regarding mean intensity, males exhibited values of 13.06 ± 1.2 for *P. cyathopharynx* and 12.02 ±1.4 for *R. congolensis*. In females, the corresponding values were 4.06 ±0.3 for *P. cyathopharynx* and 6.4 ± 0.5 for *R. congolensis* (Figure 4B). A significant difference was observed in mean intensity between male and female fish (Mann-Whitney (U) test ; $p < 0.05$). Males were thus more heavily infested by both species than females.

Stomach infestation: Analysis of prevalence (Figure 4A) showed that the highest values in males were recorded for *Paracamallanus cyathopharynx* (92.93%), *Procamallanus laeviconchus* (87.28%) and *Anisakis* sp. (3.53%). In contrast, females exhibited higher prevalence for *Rhabdochona congolensis* (43.68%), *Brevimulticaecum heterotis* (37.55%), *Camallanus polypteri* (44.04%) and *Contracaecum* sp. (3.97%). The lowest prevalence values for *P. cyathopharynx* (44.76%), *P. laeviconchus* (41.88%) and *Anisakis* sp. (2.53%) were observed in females, whereas the lowest values for *R. congolensis* (10.60%), *B. heterotis* (10.25%), *C. polypteri* (5.91%) and *Contracaecum* sp. (3.53%) were recorded in males. The Chi-square (χ^2) test revealed a significant difference in prevalence between male and female fish ($p < 0.05$). Therefore, males were more heavily parasitized by *P. cyathopharynx*, *P. laeviconchus* and *Anisakis* sp., whereas females predominantly harboured *R. congolensis*, *B. heterotis*, *C. polypteri* and *Contracaecum* sp. Regarding mean intensity, the highest values in males were 19.93 ± 2.2 for *P. cyathopharynx*, 16.70 ± 1.3 for *P. laeviconchus* and 4.20 ± 0.6 for *Anisakis* sp., whereas the lower intensities concerned *R. congolensis* (4.20 ±0.2), *B. heterotis* (4.83 ±0.4), *C. polypteri* (5.91 ±0.7) and *Contracaecum* sp. (3.82 ±0.1) (Figure 4B). In females, mean intensities were 4.06 ± 0.1 for *P. cyathopharynx* and 6.4 ± 2.1 for *R. congolensis*. The Mann–Whitney (U) test indicated a statistically significant difference in mean parasite intensity between male and female hosts.

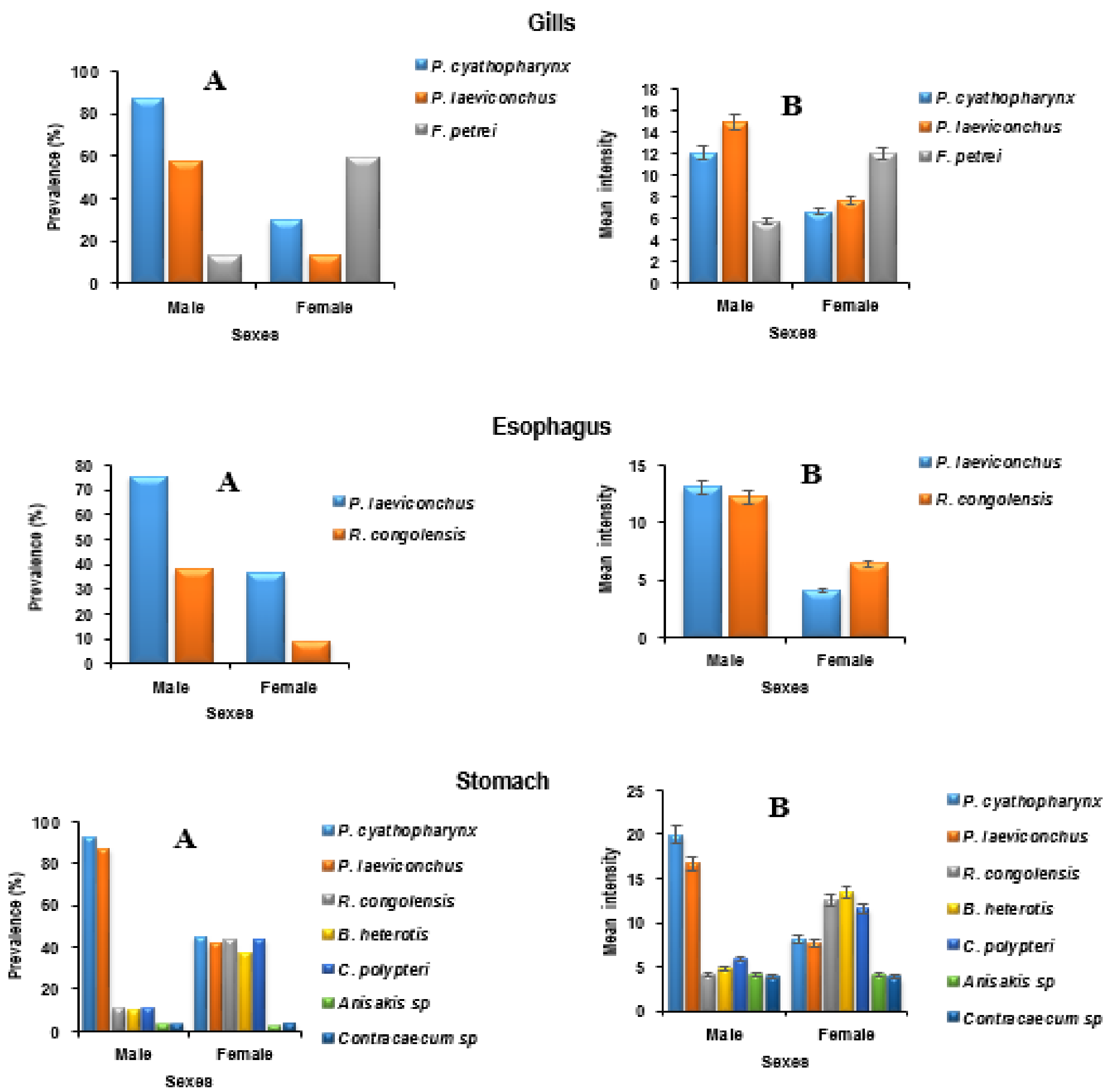

Figure 4 : Prevalence (A) and Mean intensity (B) of gills, esophageal, and stomach Nematode parasites of *Clarias anguillaris* according to host sex in the river Bandama à N'Denou. *P= Paracamallanus cyathopharynx P=Procamallanus laeviconchus, Contracaecum sp, F= Falcaustra petrei, R=Rhabdochona congolensis, B= Brevimulticaecum heterotis, C= Camallanus polypteri and Anisakis sp*

Intestinal infestation: Prevalence analysis (Figure 5A) showed that in males, infection rates were 58.30% for *P. cyathopharynx*, 49.82% for *P. laeviconchus*, 13.43% for *Contracaecum* sp., 84.45% for *F. petrei*, 48.41% for *R. congolensis*, 50.18% for *S. spiralis*, 15.19% for *B. heterotis*, 3.18% for *C. polypteri* and 24.38% for *Anisakis* sp. In females, prevalence was higher for *P. cyathopharynx* (98.19%), *P. laeviconchus* (98.92%), *Contracaecum* sp. (55.23%) and *B. heterotis* (44.04%), whereas *F. petrei* (48.01%), *R. congolensis* (21.66%) and *S. spiralis* (21.29%) were less frequent. *C. polypteri* (4.33%) and *Anisakis* sp. (23.47%) were recorded in both sexes. The Chi-square

(χ^2) test indicated that these sex-related differences in fish prevalence were statistically significant ($p < 0.05$). For mean intensity (Figure 5B), males exhibited values of 9.74 ± 1.4 for *P. cyathopharynx*, 6.16 ± 0.3 for *P. laeviconchus*, 4.89 ± 0.1 for *Contracaecum* sp., 18.21 ± 2.3 for *F. petrei*, 11.91 ± 1.1 for *R. congolensis*, 12.63 ± 1.5 for *S. spiralis*, 7.58 ± 0.8 for *B. heterotis*, 4.11 ± 0.5 for *C. polypteri* and 9.59 ± 1.2 for *Anisakis* sp. In females, mean intensities were 19.49 ± 1.7 for *P. cyathopharynx*, 18.40 ± 2.3 for *P. laeviconchus*, 9.89 ± 0.4 for *Contracaecum sp*., 5.38 ± 0.8 for *F. petrei*, 4.15 ± 0.3 for *R. congolensis*, 5.47 ± 1.1 for *S. spiralis*, 12.18 ± 1.2 for *B. heterotis*, 3.58 ± 0.1 for *C. polypteri* and 10.01 ± 1.6 for *Anisakis* sp. The Mann-Whitney (U) test confirmed that males were significantly parasitized by *F. petrei*, *R. congolensis* and *S. spiralis*, whereas females exhibited higher parasite intensities of *P. cyathopharynx*, *P. laeviconchus*, *Contracaecum* sp. and *B. heterotis* ($p < 0.05$). *C. polypteri* and *Anisakis* sp. were present in both sexes without a notable difference (Mann-Whitney (U) test ; $p < 0.05$).

Infestation of the body cavities: In females, prevalence values were 94.22% for *P. laeviconchus*, 92.42% for *Contracaecum* sp., 11.55% for *F. petrei*, 28.88% for *S. spiralis*, and 13.36% for *Anisakis* sp. (Figure 5A). In contrast, males exhibited prevalence rates of 26.50% for *P. cyathopharynx*, 27.56% for *P. laeviconchus*, 46.99% for *Contracaecum* sp., 91.52% for *F. petrei*, 2.83% for *S. spiralis* and 39.93% for *Anisakis* sp. The Chi-square test (χ^2) indicated a significant difference in prevalence between male and female fish ($p < 0.05$). Males were more heavily parasitized by *Contracaecum* sp., *F. petrei*, and *Anisakis* sp., whereas females harboured higher prevalence of *P. cyathopharynx* and *P. laeviconchus*. For mean intensity (Figure 5B), males exhibited values of 7.43 ± 0.3 for *P. cyathopharynx*, 5.26 ± 0.2 for *P. laeviconchus*, 10.18 ± 1.1 for *Contracaecum* sp., 13.16 ± 1.3 for *F. petrei*, 2.87 ± 0.1 for *S. spiralis* and 10.85 ± 0.8 for *Anisakis* sp. In females, mean intensities were 13.11 ± 1.5 for *P. cyathopharynx*, 13.68 ± 1.7 for *P. laeviconchus*, 3.62 ± 0.4 for *Contracaecum* sp., 4.84 ± 0.3 for *F. petrei*, 2.60 ± 0.1 for *S. spiralis* and 3.19 ± 0.5 for *Anisakis* sp. According to the Mann–Whitney (U) test, mean parasite intensity differed significantly between male and female hosts ($p < 0.05$). Consequently, males were parasitized by *Contracaecum* sp., *F. petrei* and *Anisakis* sp., whereas females harboured higher levels of *P. cyathopharynx* and *P. laeviconchus*.

Gonadal infestation: Prevalence analysis (Figure 5A) showed that the highest values were recorded in males, with 39.93% for *R. congolensis* and 3.89% for *F. petrei*. In contrast, females exhibited lower prevalence rates of 3.25% for *R. congolensis* and 7.58% for *F. petrei*. A significant difference was observed in prevalence between male and female fish (Chi-square (χ^2) test ; $p < 0.05$). Regarding mean intensity (Figure 5B), males exhibited values of 15.30 ± 1.7 for *F. petrei* and 4.45 ± 0.3 for *R. congolensis*, whereas females showed 6.14 ± 1.3 for *F. petrei* and 4.33 ± 0.2 for *R. congolensis*. The Mann-Whitney (U) test confirmed that males were significantly more infested by these two species than females ($p < 0.05$).

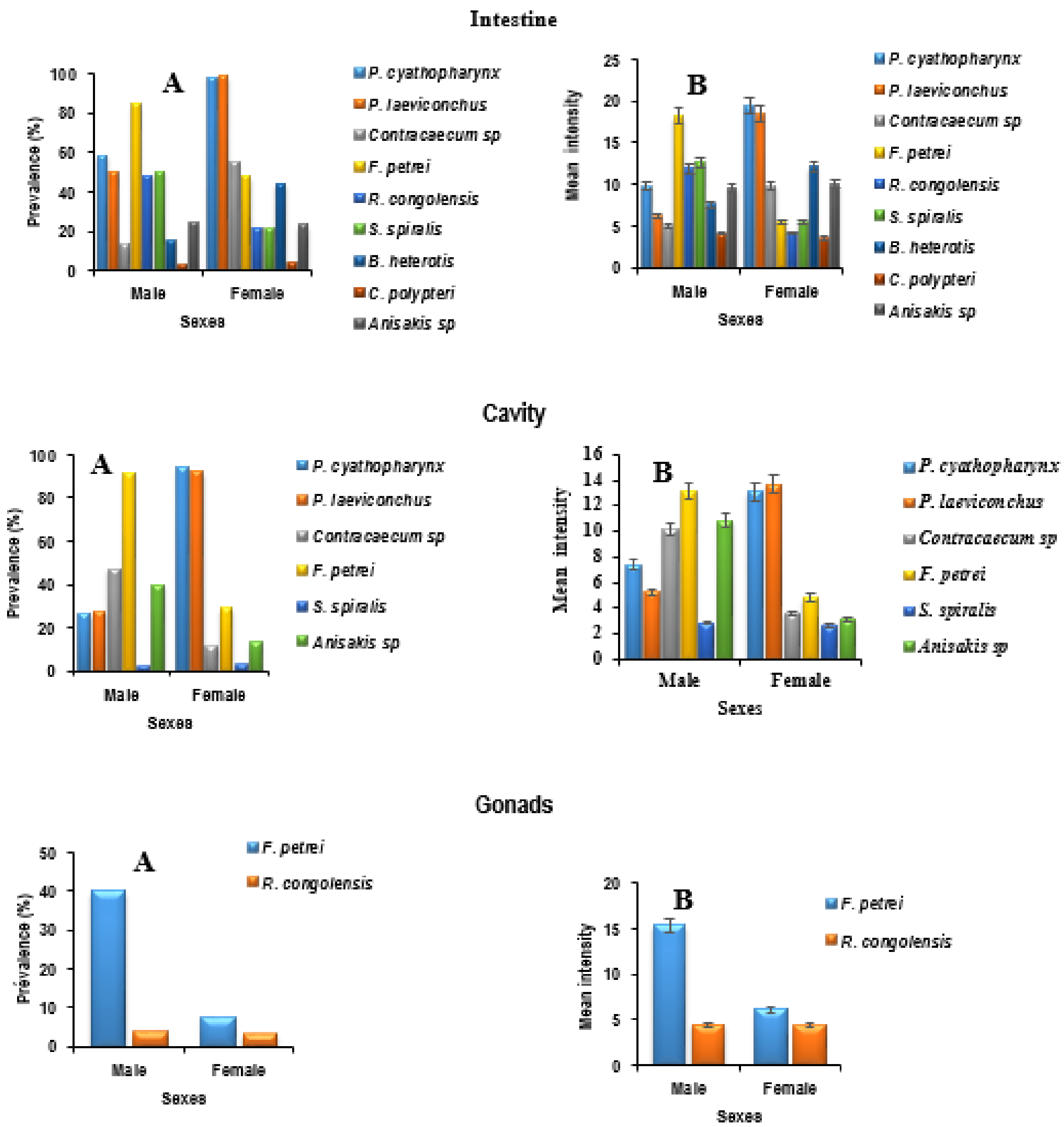

Figure 5 : Prevalence (A) and Mean intensity (B) of parasitic nematodes of *Clarias anguillaris* according to host sex in the Bandama River at N'Denou. P = *Paracamallanus cyathopharynx*, P= *Procamallanus laeviconchus*, *Contracaecum sp*, F= *Falcaustra petrei*, R=*Rhabdochona* congolensis, *Spirocamallanus* S= *spiralis*, B= *Brevimulticaecum heterotis*, C= *Camallanus polypteri* and *Anisakis sp*

Seasonal variation of *Clarias anguillaris* infestation by Nematodes

- Gill infestation: The prevalence and mean intensity of gill parasites vary seasonally (Figure 6). Maximum prevalence was observed during the major and minor dry seasons for *Paracamallanus cyathopharynx* (68.09 %), *Procamallanus laeviconchus* (52.08 %) and *Falcaustra petrei* (47.92 %), while minimum values occurred during the rainy season (17.78-51.06 %) (Figure 6A). The differences in prevalence between the dry and rainy seasons were statistically significant (Chi-square (χ^2) test ; $p < 0.05$). Mean intensities follow the same pattern, with maxima in January (15.79 ± 1.8 – 17.43 ± 1.5) and minima during the rainy season (3.38 ± 0.3 – 7.25 ± 1.2), as confirmed by the Kruskal-Wallis (K) test ($p < 0.05$) (Figure 6B). Thus, gill infestation was significantly higher during the dry season.

- Oesophageal infestation: Maximum prevalence was observed in January and August for *P. laeviconchus* (69.77 %) and *R. congolensis* (41.67 %), while minimum prevalence occurred in June and October (8.89-51.06%) indicating stronger infestation in the dry season (Figure 6AA significant difference was observed between the dry and rainy seasons (Chi-square test (χ^2) ; $p < 0.05$). Mean intensities follow the same trend, with maxima in February (14.87±1.7-15.85 ±1.4) and minima in April and October (4.26±0.1-6.4 ±0.4) (Figure 6B). The differences were statistically significant (Kruskal-Wallis (K) test ; $p < 0.05$). *P. laeviconchus* is the predominant species and *R. congolensis* is secondary.

- Stomach infestation: Maximum prevalence of gastric parasites *P. cyathopharynx*, *P. laeviconchus*, *R. congolensis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, *Anisakis* sp. and *Contracaecum* sp. was recorded during the major dry season (January–February), while minima occurred during the rainy seasons (0–53.33 %) (Figure 6A). The differences observed in infestation rates between the dry and rainy seasons were found to be statistically significant (Chi-square (χ^2) test ; $p < 0.05$). Mean intensities follow a similar pattern, with maxima in December–January (5.33 ± 0.1 - 23.94 ± 2.3) and minima during the rainy season (5.73 ± 0.2), as established by the Kruskal-Wallis test (K) ($p < 0.05$) (Figure 6B). This indicates that stomach infestation was significantly higher during the dry season.

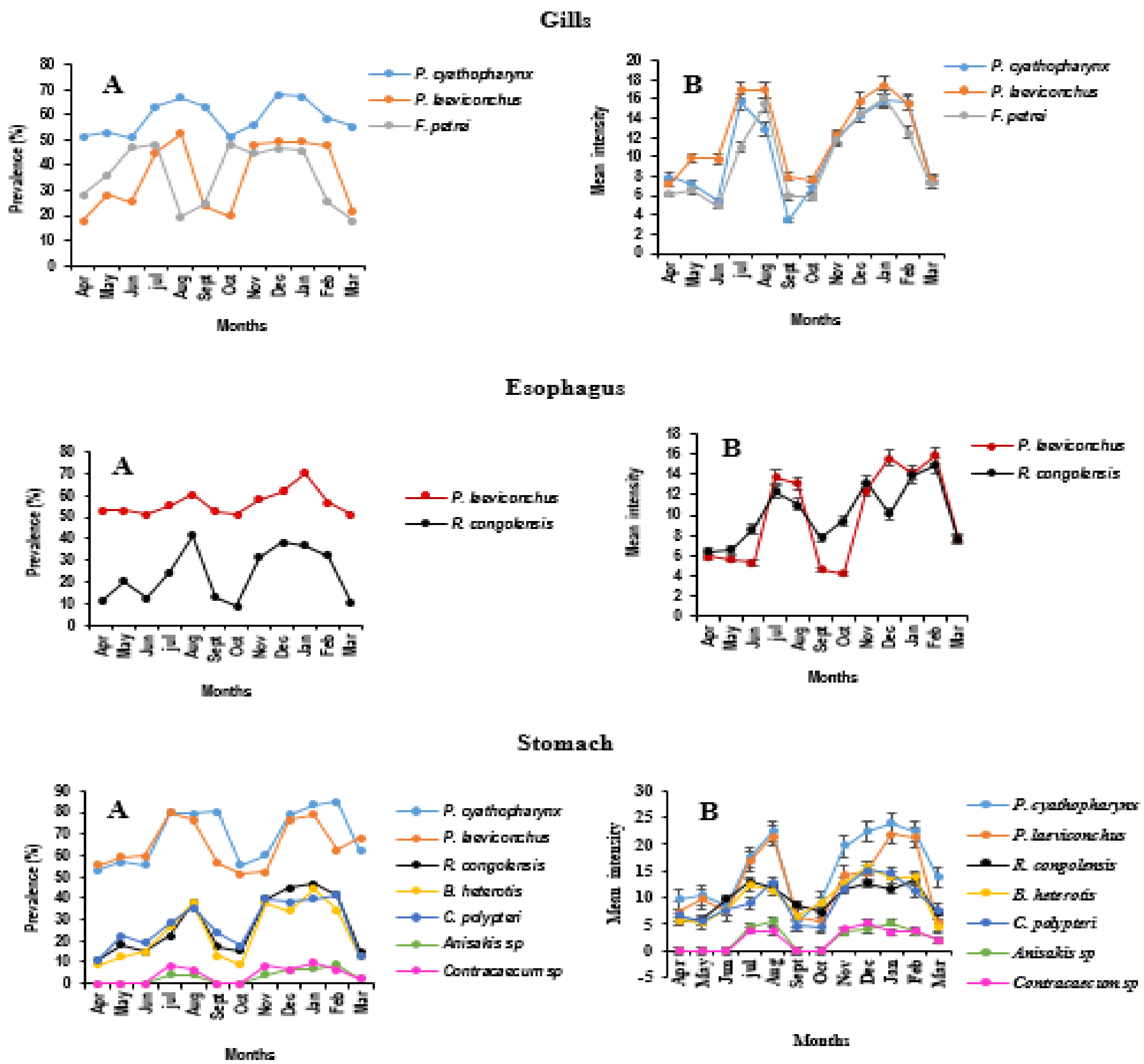

Figure 6 : Seasonal variations in the Prevalence (A) and Mean intensity (B) of Nematode P= *Paracamallanus cyathopharynx*, P= *Procamallanus laeviconchus*, R= *Rhabdochona congolensis*, B= *Brevimulticaecum heterotis*, C= *Camallanus polypteri*, *Anisakis* sp. and *Contracaecum* sp species parasitic on the gills, esophagus and stomach of *Clarias anguillaris* sampled in the Bandama River. Apr : April ; May. Jun, Jul : July ; Aug : August août ; Sept : September, Oct : October ; Nov : November, Dec : December, Jan : January ; Feb : February ; Mar : March.

- Intestinal infestation: Maximum prevalence (P) (Figure 7A) and intensity (IM) (Figure 7B) of intestinal nematodes (*P. cyathopharynx* (P= 97.92% ; IM=23.32± 2,2), *P. laeviconchus* (P=91.84% ; IM=23.38±2,1), *F. petrei* (P=85.11% ; IM=19.39±1,7), *R. congolensis* (P= 47.92 % ; IM=13.51±2,1), *S. spiralis* (P= 53.49 % ; IM=14.14±1,6), *B. heterotis* (P=48.84% ; IM=14.3±1,3), *C. polypteri* (P=85.11% ; IM=19.39±1,7), *Contracaecum* sp. (P=48.84% ; IM=12.45±0,9) and *Anisakis* sp. (P=44.68% ; IM=14.93±1,4) were observed in December, while minima occurred during the rainy seasons. Seasonal differences in prevalence and intensity were significant, confirming higher intestinal infestation during the dry season (Chi-square(χ^2) test and Kruskal-Wallis (K) test ; $p < 0.05$).

- Body Cavity infestation: Maximum prevalence of body cavity parasites (*P. cyathopharynx*, *P. laeviconchus*, *Contracaecum* sp., *F. petrei*, *S. spiralis*, *Anisakis* sp.) was recorded during the major dry season (December–February), with minima in the rainy seasons (Figure 7A). Mean intensities follow the same trend (3.67 ± 0.2 - 21.37 ± 2.3) (Figure 7B), with significant seasonal differences indicating higher infestation during the dry season compared to the rainy season (Chi-square (χ^2) test and Kruskal-Wallis (K) test ; $p < 0.05$).

-Gonadal parasites : Maximum prevalence (Figure 7A) and intensity (Figure 7B) were observed during the major dry season (January), with values of 43.48 % and 19.18 ± 1.7 for *F. petrei*, and 8.33 % and 6 ± 1.01 for *R. congolensis* (Figure 6). Minima occurred during the rainy seasons, with significantly lower or null values. The observed seasonal differences were statistically significant, indicating a higher parasitic infestation of *Clarias anguillaris* gonads during the dry season (Chi-square (χ^2) test and Kruskal-Wallis (K) test ; $p < 0.05$).

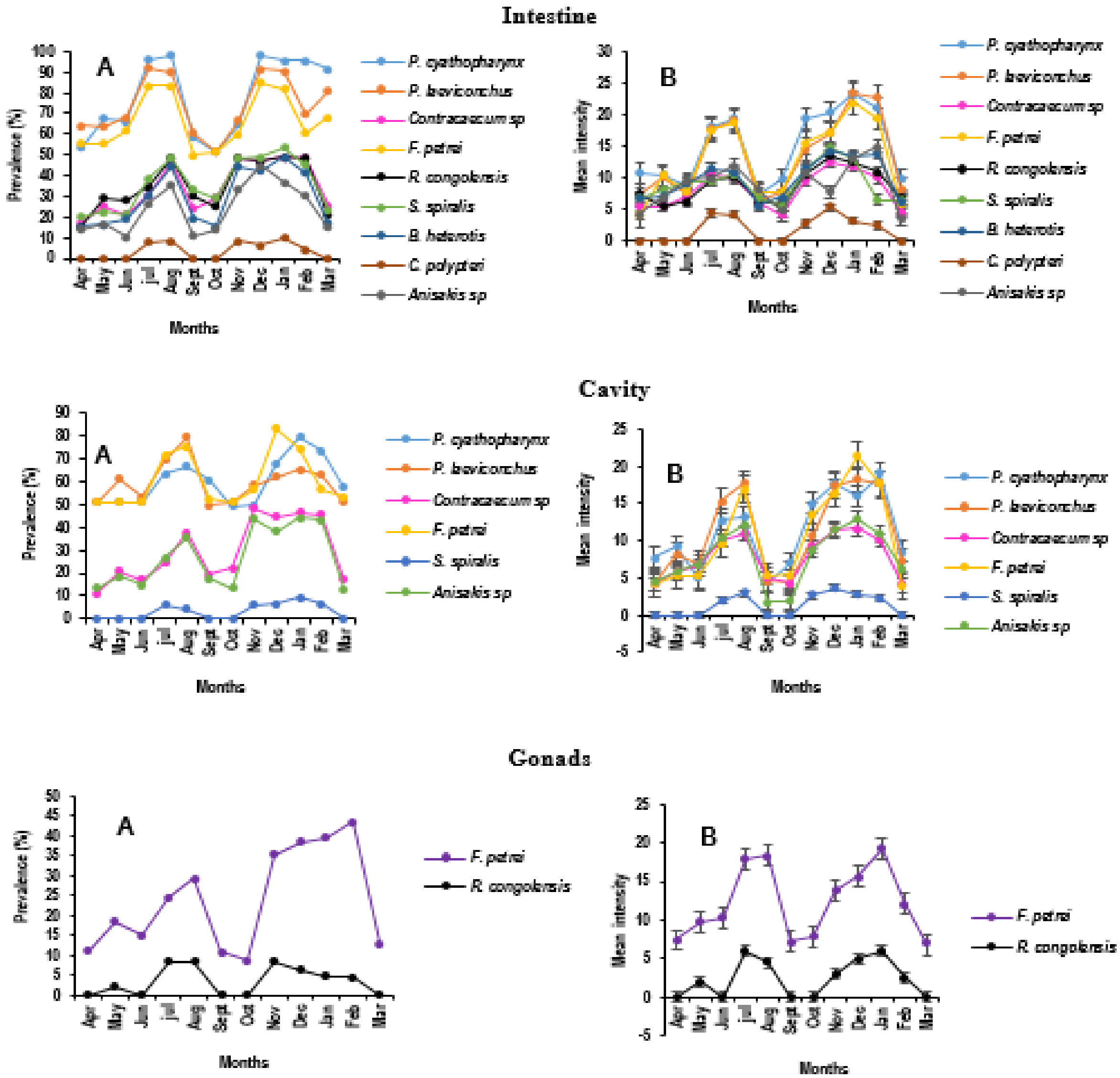

Figure 7 : Seasonal variations in the Prevalence (A) and Mean intensity (B) of Nematodes P= *Paracamallanus cyathopharynx*, P= *Procamallanus laeviconchus*, R= *Rhabdochona congolensis*, S= *Spirocamallanus spirale*, B= *Brevimulticaecum heterotis*, C= *Camallanus polypteri*, *Anisakis sp.*, F= *Falcaustra petrei* and *Contracaecum sp* parasitic species in the intestinal cavity general cavity and gonads of *Clarias anguillaris* sampled in the Bandama River. Apr : April ; May. Jun, Jul : July ; Aug : August août ; Sept : September, Oct : October ; Nov : November, Dec : December, Jan : January ; Feb : February ; Mar : March.

DISCUSSION

The study of various organs infested by Nematode parasites in *Clarias anguillaris* captured from the Bandama river allowed the identification of nine Nematode species. Previous studies by Kabré (1997) and Sinaré *et al.* (2021) reported the presence of 11 and 6 Nematode species, respectively, in *Clarias anguillaris* in Burkina Faso. Variations in species richness could be attributed to differences in physicochemical water parameters and the nature of the study environment (lentic or lotic) (El-Tantawy *et al*., 2023). Furthermore, species such as *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Rhabdochona congolensis*, *Falcaustra petrei*, *Anisakis* sp., and *Contracaecum* sp., which were found in both Burkina Faso and Côte d'Ivoire, can be considered cosmopolitan parasites. Additionally, these differences may be related to site-specific variations, water contamination levels, or anthropogenic activities (Nabala *et al*., 2024). Consequently, parasitic infestations and their diversity appear to be directly influenced by human activities and environmental contamination. Moreover, the presence of these nematodes in this fish species may be attributed to the opportunistic feeding habits of *C. anguillaris* (Abdel-Gaber *et al*., 2015). Indeed, such feeding behavior may contribute to increased parasite loads in the digestive tract, as the fish consumes planktonic crustaceans, aquatic insects, and benthic organisms containing infective parasite stages. These results are in agreement with the findings reported by Tossavi *et al*. (2024). The results of this study indicate that Nematode parasites of *Clarias anguillaris* exhibit organ-specific distribution, with each species showing a marked affinity for particular attachment sites within the host. *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Brevimulticaecum heterotis*, *Rhabdochona congolensis*, *Contracaecum* sp., and *Spirocamallanus spiralis* were predominantly found in the intestine, whereas *Camallanus polypteri* mainly infested the stomach, and *Falcaustra petrei* along with *Anisakis* sp. primarily parasitized the body cavity. The high prevalence of intestinal infestation may be explained by the favourable physiological and nutritional conditions this organ provides. The intestine offers not only direct access to a consistent nutrient source but also an environment conducive to parasite survival in terms of temperature, nutrient availability, and physiological conditions (Sinaré *et al*., 2021). *Camallanus polypteri* exhibits a particular affinity for the stomach mucosa, where the rich vascularization and relatively stable environment facilitate its attachment and feeding (Sorour & Hamouda, 2019). Infestation of the body cavity by *F. petrei* and *Anisakis* sp. can be attributed to the unique characteristics of this anatomical space, which provides a stable, relatively isolated environment, ideal for prolonged survival and development (Barson, 2004). Moreover, as *Clarias* is an omnivorous fish that consumes a wide range of food items, including other fish and aquatic invertebrates, the likelihood of ingesting infective nematode larvae increases. Once inside the host, larvae may use the body cavity as a transitional habitat or, in rare freshwater cases, infect marine mammals in the life cycle of *Anisakis*. These findings obtained herein support the observations by Houénou Sèdogbo *et al*. (2019) on nematodes in *Clarias gariepinus* from the Upper Ouémé delta in southern Benin and with Noor El-Din *et al*. (2009), who investigated the histopathological alterations induced by the spiruroid nematode *Procamallanus laeviconchus* in the stomach and intestine of Nile catfish (*Clarias gariepinus*) from Egypt. The differences in nematode infestation between male and female *Clarias anguillaris* can be attributed to physiological and hormonal factors. The high infestation in males may be related to the effects of testosterone, a hormone essential for the development of secondary sexual characteristics and reproduction, but which can also have immunosuppressive effects (Poulin, 1996 ; Ugbor *et al*., 2014). During the reproductive period, testosterone levels increase in males, weakening their immune system and making them more susceptible to parasitic infections, including Nematodes. Moreover, males are often more exposed to parasites due to behaviors such as competition for females or aggression toward other males. These behaviors may cause injuries that facilitate nematode penetration. Testosterone also influences male responses to stress, including thermal stress during the dry season. This stress, combined with aggression and competition, may further increase vulnerability to nematode infestation. In contrast, higher nematode prevalence in females may be linked to an energetic trade-off, with resources prioritized for reproduction at the expense of immune defenses (Ayawei *et al*., 2020 ; Sadauki *et al*., 2022). This study also showed that *Clarias anguillaris* are more susceptible to *Procamallanus laeviconchus*, *Paracamallanus cyathopharynx*, and *Anisakis* sp. during the dry season. This high infestation is associated with reduced water levels and overcrowding. Lower water levels concentrate fish in smaller areas, facilitating parasite transmission through closer contact and accumulation of eggs or larvae in feces. Competition for oxygen and food adds stress, further weakening immunity (Oniye *et al*., 2004). Thermal stress during the dry season exacerbates susceptibility, impairing immunity and making tissues more vulnerable to nematode penetration (Oniye *et al*., 2004 ; Echi *et al*., 2009). Elevated temperatures also promote nematode activity and development, increasing environmental parasite abundance (Alves *et al*., 2008 ; Oliveira et Boeger, 2009). Similar patterns have been reported in *Clarias gariepinus* (Oniye *et al*., 2004 ; Biu *et al*., 2014), indicating that the dry season is critical for the sanitary management of *Clarias* populations. Conversely, the highest prevalence and mean intensity of *Contracaecum* sp. infestation during the rainy season is explained by interdependent ecological and biological factors. Rising water levels increase the availability of intermediate hosts, such as small fish and invertebrates, which are consumed by *Clarias anguillaris*, enhancing exposure to infective larvae (Sadauki *et al*., 2022). Additionally, the rainy season redistributes nutrients and organic matter in the water, creating favorable conditions for the development of free-living or intermediate parasite stages.

CONCLUSION AND APPLICATION OF RESULTS

This study investigated the diversity of parasitic nematodes infecting the African catfish, *Clarias anguillaris*, in the Bandama River. Nine species were identified : *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Contracaecum sp*., *Falcaustra petrei*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, and *Anisakis sp*., distributed across various host organs. Seasonal analysis revealed significant fluctuations in infestation levels. The dry season emerged as a critical period, characterized by increased parasitic prevalence, likely due to higher pollutant concentrations and deteriorating water quality. In contrast, the rainy season saw reduced infestations, likely resulting from pollutant dilution and improved environmental conditions. These findings provide a valuable biological indicator of the ecological status of the Bandama River and supply essential data for developing sustainable fisheries management strategies, while also supporting consumer health protection and the conservation of this economically important species.

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