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Seasonal Variation of Nematode Parasites and Condition Factor in the Catfish Clarias Anguillaris from the Bandama River at N'Denou (Côte d'Ivoire)

Ahou Rosine Kouame
Kassi Georges Blahoua
Research Unit on Hydrobiology, Laboratory of Natural Environments and Biodiversity Conservation, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire
Yedehi Euphrasie Adou
Research Unit on Ecology and Biodiversity, Laboratory of Ecology and Sustainable Development, Nangui Abrogoua University, Abidjan, Côte d'Ivoire
Essetchi Paul Kouamelan
Research Unit on Hydrobiology, Laboratory of Natural Environments and Biodiversity Conservation, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire

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Abstract

The African catfish *Clarias anguillaris* is widely exploited in aquaculture due to its high performance and nutritional value, thereby contributing to food security and job creation. However, in the Bandama River at N'Denou, an area subjected to anthropogenic activities, this species is exposed to parasitic nematodes that may affect its production. No parasitological study had previously been conducted in this area. The present study aimed to inventory nematode species, analyze their seasonal diversity, and assess their impact on the condition factor of *C. anguillaris*. A total of 560 fish were collected between April 2024 and March 2025. Parasites were searched for, identified, and counted using standard methods. Chi-square

(X^2), Mann-Whitney (U), and Kruskal-Wallis (K) tests were applied. Nine species were identified : *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) were observed in the intestine, particularly for *P. cyathopharynx*, *P. laeviconchus*, and *F. petrei*. During the dry season, infestations reached their peak, with high values 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). Shannon–Weaver (H′ = 3.54 bits/ind), Simpson (D = 0.86), and evenness (E = 0.86) indices indicated high diversity during this period. The condition factor of infested fish (K = 0.27 ± 0.01) was significantly lower than that of uninfested fish (K = 0.68 ± 0.02), indicating a negative impact of parasitic infestations on the physiological state of individuals. This study characterizes the parasitic fauna of *C. anguillaris*. It also highlights periods of vulnerability of the species and the deleterious effects of parasitic nematodes. These findings provide a solid scientific basis for the development of sustainable management strategies aimed at reconciling the conservation of this fishery resource with the improvement of local livelihoods.

Keywords: Clarias anguillaris – parasitic nematodes – condition factor – Bandama River – Côte d’Ivoire

Introduction

Parasites are living organisms, either animal or plant, that develop at the expense of a host. They may live permanently on or within the host, or only during a specific stage of their life cycle. According to Chong et al. (2011), parasites can affect the survival, physiology, behavior, and overall fitness of aquatic organisms. Furthermore, the Food and Agriculture Organization (Lima, 2011) reported that some fish parasites are responsible for zoonotic diseases.

Among fish parasites, nematodes are important endoparasites characterized by heteroxenous life cycles involving one or more intermediate hosts (Owolabi, 2008). They infect various organs, including the gills, esophagus, stomach, intestine, body cavity, and kidneys of fish. These parasitic infestations constitute a major pathological factor in aquatic environments and can have severe consequences for both aquaculture systems and natural fish populations (Sorour and Hamouda, 2019 ; Sadauki et al., 2022 ; Nababa, 2024). In aquaculture systems, they are responsible for high morbidity and mortality rates, reduced zootechnical performance, and deterioration of product sanitary quality, leading to significant economic losses (Morsy et al., 2013 ; Morsy et al., 2015 ; Heba et al., 2018 ; Nababa, 2024). In natural populations, these parasitic infections can impair host survival, growth, and reproductive success, thereby contributing to ecological imbalances and alterations in the dynamics of aquatic communities (Douëllou, 1992 ; Paperna, 1996 ; Bondad-Reantaso et al., 2005). Therefore, it is essential to conduct in-depth research on these pathogens in order to improve prevention, control, and management strategies for their impacts. Such information is crucial for optimizing fish production in both natural ecosystems and aquaculture systems.

Thus, apart from the study by Sinaré et al. (2021) on nematode parasite infestation in *Clarias anguillaris* in Burkina Faso, there are no data on the parasitic infestation of *Clarias anguillaris*, particularly in the Bandama River at N'Denou, Côte d'Ivoire. This species, however, is present in many Ivorian rivers (Yao et al., 2010 ; N'Dri, 2020), including the Bandama River in the N'Denou locality.

Indeed, *C. anguillaris* contributes significantly to local diets and is highly valued for its nutritional quality. Furthermore, due to its robustness, ability to reproduce in captivity, tolerance to low-oxygen environments, and capacity for aerial respiration, this species is widely used in aquaculture (Legendre et al., 1992). Its farming is also considered a viable strategy to improve food security, reduce poverty, and generate employment (Adande et al., 2015). Consequently, this fish is widespread and plays a crucial economic role for local communities. However, the Bandama River at N'Denou, which serves as a landing site for *C. anguillaris*, remains exposed to various forms of pollution, particularly those arising from illegal artisanal gold mining and agricultural activities. These environmental disturbances can degrade water quality and create conditions favorable for the development and proliferation of parasites, particularly nematodes, in this habitat.

This study aimed to determine the species composition, analyze the seasonal variation of parasitic and diversity indices, and assess the condition factor of *Clarias anguillaris* in the Bandama River at N'Denou.

Material and Methods

Description of the study area

Located entirely in Côte d'Ivoire, the Bandama River drains a basin of approximately 97,500 km², extending between longitudes 3°50′ and 7° W and latitudes 5° and 10°20′ N. It originates in the northern part of the country, between the towns of Korhogo and Boundiali, and stretches over a length of about 1,050 km before flowing into the Grand-Lahou lagoon, where it empties into the Atlantic Ocean (Lozo et al., 2019). Along its course, the river crosses several climatic zones before reaching its outlet at Grand-Lahou (Koné, 2002). The hydrological regime of the Bandama River is characterized by strong seasonal variability. According to Brou (2005), it is marked by the alternation of two rainy seasons (May to July and September to October) and two dry seasons (July to August and November to April), which directly influence the hydrological functioning of the river and its watershed. Beyond its hydrological importance, the Bandama River represents a strategic resource for the country's socio-economic development. It plays a key role in agricultural activities and hydroelectric power generation, particularly through the Kossou and Taabo dams, which contribute significantly to national energy production (Touré, 2015). The study area corresponds to the locality of N'Denou, located in the southern part of the Bandama River, upstream of the Singrobo-Ahouaty dam. This sampling station lies between latitudes 6°10′ and 6°11′ N and longitudes 4°59′ and 5°00′ W (Figure 1). This area is subjected to significant environmental pressures related to human activities, particularly intensive agriculture and illegal artisanal gold mining. The environment is characterized by dense aquatic vegetation, mainly composed of water hyacinths, which cover more than 10% of the water surface, while forest cover is estimated at approximately 5%. The river substrate is predominantly sandy, with localized areas composed of rocks, mud, and clay. Near the N'Denou station, subsistence crop plantations, such as maize and eggplant, are observed, along with a classified forest. The riverbanks are also bordered by forest formations and plantations of oil palm and cocoa trees. The average depth of this aquatic area is approximately 7 meters.

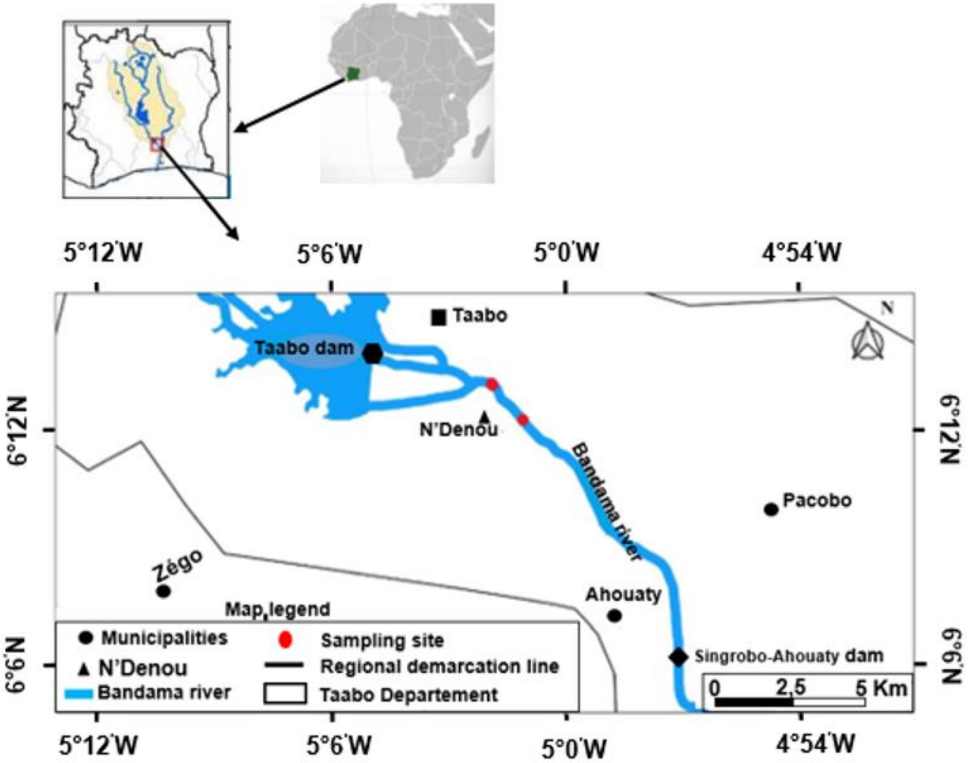

Figure 1: Geographical location of Bandama River at the N'Denou sampling station

Fish sampling and parasite collection

Field sampling was carried out from April 2024 to March 2025 in the Bandama River at N'Denou. During this period, 560 specimens of *Clarias anguillaris* were obtained using a combination of experimental gear and traditional artisanal fishing methods representative of local practices. All captured fish were quickly transferred to the laboratory for further examination. Species identification relied on the dichotomous keys described by Paugy et al. (2003), providing accurate taxonomic assignment. Individuals of *Clarias anguillaris* were carefully dissected to access the full digestive system. The alimentary canal was excised and partitioned into specific anatomical regions, including the gills, esophagus, stomach, intestine, body cavity, and gonads. Each portion was placed separately in Petri dishes filled with 0.9% physiological saline, following the procedure described by Sadauki et al. (2022). For improved detection of parasites, each section was opened longitudinally and observed under a stereomicroscope at magnifications ranging from 10× to 30×. This method facilitated the identification of helminths, which were often recognized by their active movements in the saline solution. The recovered parasites were then sorted into groups based on their morphological characteristics. The identification of nematodes was conducted using established taxonomic references, including Yamaguti (1961), Kabré (1997), and Gibbons (2010), all of which are widely used in fish parasitology. Following identification, the parasites were counted to determine their abundance and distribution within the different parts of the digestive tract. They were subsequently fixed in a 5% formalin solution to preserve their structure, and later transferred into 70% ethanol for long-term storage and future analyses.

Data Analysis

Condition Factor (K)

Fulton's condition factor (K) assumes that fish weight is proportional to the cube of its length and is commonly used to evaluate the overall health status of fish, both at the individual and population levels. For each specimen, total length, standard length, and body weight were recorded. An allometric relationship, in which the exponent *b* is considered constant, was applied to compare the condition among different categories of fish.
Accordingly, Fulton's condition factor (K) was calculated using the following formula :

$$K = \frac{W \times 100}{L^b} \quad \text{(Klemm } et\ al. \text{ 1992),}$$

Where W = weight of fish (g), L = standard length of the fish (cm), b= coefficient of allometry considered equal to 3).

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

Parasite and diversity indices

The terms "Prevalence" and "Mean intensity" were defined according to Bush *et al*. (1997).
Prevalence (P%) is the percentage ratio between the number of hosts infested (N) by a given parasite species and the number of fish examined (H).

$$P = \frac{N}{H} \text{ x100}$$

A parasite species was classified according to its prevalence : common **(**core**)** if prevalence exceeded 50%, intermediate (secondary) if prevalence ranged between 10% and 50%, and rare if prevalence was below 10%, following the criteria of Valtonen et al. (1997).

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

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

The structure of the parasite communities was evaluated using the Shannon–Weaver diversity index (H'), Pielou's evenness index (E), and Simpson's dominance index (D). All calculations were performed using PAST (Paleontological Statistics) software.

Shannon-Weaver index (H') :

$$H' = -\sum_{i=1}^{S} \frac{N_i}{N} \times \log_2\left(\frac{N_i}{N}\right)$$

Pielou's evenness index (E)

$$E = \frac{H'}{H'max}$$

Simpson index (D)

$$S = 1\text{-}D$$

Statistical Analysis

Statistical tests were employed to assess the significance of the observed differences in the collected data. All analyses were performed using STATISTICA 7.1, with a confidence level set at 95%. The Chi-square test (X^2) was used to examine variations in parasite infestation according to categorical parameters, such as the attachment sites of parasites on the host. This test allows determination of whether the distribution of parasites differs significantly between the groups studied. To compare parasite infestation across different seasons, the non-parametric Kruskal-Wallis test was applied, enabling the detection of significant differences among more than two independent groups. The Mann-Whitney U test was subsequently used for pairwise comparisons, for example between two specific seasons or two fish categories, to confirm significant differences observed.

Results

Specific composition

The parasitological examination of 560 *Clarias anguillaris* specimens revealed the presence of 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 in all the organs analyzed, with the greatest abundances recorded in the intestine (37%), stomach (22%), and body cavity (20%). A significant variation in parasite distribution among the different organs was confirmed by the Chi-square ((χ^2) test ($p < 0.05$).

Temporal variations in infestation

Temporal variations in parasite infestation have been assessed according to the organs examined. Overall, both prevalence and mean intensity have been higher during the dry season than during the rainy season, with seasonal differences having been statistically significant (χ^2 test for prevalence; Kruskal–Wallis test for mean intensity, $p < 0.05$).

Parasitic infestation of the gills in Clarias anguillaris

The monthly prevalence and mean intensity of *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, and *Falcaustra petrei*, parasites of the gills of *Clarias anguillaris* at the N'Denou station, are presented in Figure 2. Prevalence has ranged from 17.78% for *P. laeviconchus* and *F. petrei* in April during the long rainy season to 68.09% for *P. cyathopharynx* in December during the long dry season. Mean intensity has ranged from 3.38 ± 0.3 for *P. cyathopharynx* in September to 17.43 ± 1.5 for *P. laeviconchus* in January. The species *P. laeviconchus* and *P. cyathopharynx* have been dominant, whereas *F. petrei* has been secondary.

Parasitic infestation of the esophagus in Clarias anguillaris

The prevalence (P) (Figure 2A) and mean intensity (MI) (Figure 2B) of parasites recorded in the esophagus of *Clarias anguillaris* revealed that the highest values were observed for *Procamallanus laeviconchus* (P = 69.77% ; MI = 14.1±1.2) in January, corresponding to the long dry season, and for *Rhabdochona congolensis* (41.67% and 14.87±1.7) in August and February, during the long and small dry seasons. Conversely, the lowest values were recorded in June, during the long rainy season, for *Procamallanus laeviconchus* (P = 51.06% ; MI = 4.26±0.1), as well as in October, during the small rainy season, for *Rhabdochona congolensis* (P = 8.89% ; MI = 6.4±0.4). In this organ, *Procamallanus laeviconchus* was the dominant species, whereas *Rhabdochona congolensis* was the secondary species.

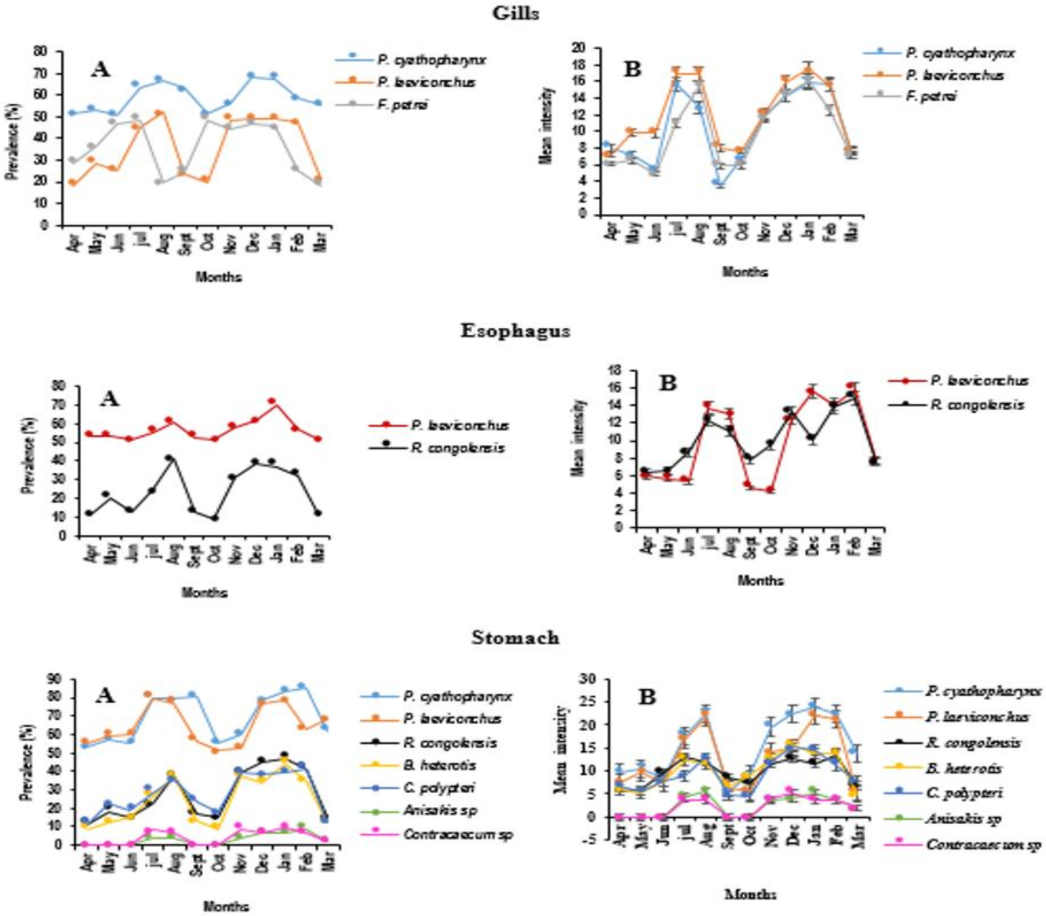

Figure 2: Seasonal variations in the Prevalence (A) and Mean intensity (B) of Nematode P = *Paramacallanus cyathopharynx*, P = *Procamallanus laevionchus*, R = *Rhabdochona congolensis*, B = *Bamachus heterotis*, C = *Camallanus* sp., Anisakis sp. and *Contracaecum* sp. species parasitic on the gills, esophagus and stomach of *Clarias anguillaris* sampled in the Bandama River. **Months:** Apr: April; May: May; Jun: June; Jul: July; Aug: August; Sept: September; Oct: October; Nov: November; Dec: December; Jan: January; Feb: February; Mar: March.

Parasitic infestation of the stomach in Clarias anguillaris

Figures 2A and 2B presented the respective fluctuations in prevalence and mean intensity of *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Rhabdochona congolensis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, *Anisakis* sp., and *Contracaecum* sp., parasites of the stomach of *Clarias anguillaris*, according to temporal variation. Prevalence has ranged from 0% for *Anisakis* sp. and *Contracaecum* sp. in April to June and in September to October, corresponding to the rainy seasons to 84.78% for *P. cyathopharynx*. Mean intensity has ranged from 0 for *Anisakis* sp. and *Contracaecum* sp. because they have been absent to 23.94 ± 2.3 for *P.*

cyathopharynx. In this organ, *Procamallanus laeviconchus* and *Paracamallanus cyathopharynx* were the dominant species, whereas *Rhabdochona congolensis*, *Brevimulticaecum heterotis*, and *Camallanus polypteri* were considered secondary species. The species *Contracaecum* sp. and *Anisakis* sp. were rare species.

Parasitic infestation of the intestine in Clarias anguillaris

The intestine has exhibited the highest parasite diversity, with all nine recorded species : *P. cyathopharynx*, *P. laeviconchus*, *R. congolensis*, *Spirocamallanus spiralis*, *B. heterotis*, *C. polypteri*, *Anisakis* sp., *F. petrei* and *Contracaecum* sp. Prevalence has ranged from 0% for *R. congolensis* and *C. polypteri* in April to June and in September to October, corresponding to the rainy seasons to 97.92% for *P. cyathopharynx* in August during the small dry season (Figures 3A). Mean intensity (Figures 3B) has varied from 0 for species that have been absent during the rainy season to 23.38 ± 2.1 for *P. laeviconchus* in January during the long dry season. Among non-zero observations, the lowest value has been 3.57 ± 0.1 for *Anisakis* sp in April, corresponding to the long rainy season.

Parasitic infestation of the general cavity in Clarias anguillaris

Seasonal variations in parasite infestation were evident in *Clarias anguillaris*. Prevalence and mean intensity were generally higher from December to February corresponding to the long dry season, and lower in April to June and in September to October, corresponding to the rainy seasons. The highest prevalence values were recorded for *Falcaustra petrei* (82.98%), *Paracamallanus cyathopharynx* (79.07%), P*rocamallanus laeviconchus* (79.17%), *Contracaecum* sp. (47.91%), and *Anisakis* sp. (44.19%), while *Spirocamallanus spirale* showed a lower prevalence (9.30%) and was absent during the rainy seasons. Similarly, mean intensities were highest during the long dry season and lowest in the rainy seasons. Among the recorded parasites, *P. cyathopharynx* and *F. petrei* were the dominant species, whereas *Anisakis* sp. and *Contracaecum* sp. were secondary, and *S. spirale* was rare.

Parasitic infestation of the gonads in Clarias anguillaris

Analysis of Figure 3A indicated that the highest prevalence values were recorded for *Falcaustra petrei* (43.48%) in January and *Rhabdochona congolensis* (8.33%) in November, corresponding to the long dry season. In contrast, the lowest values were observed during the small rainy season, particularly for *Falcaustra petrei* (8.89%) in October, whereas *Rhabdochona congolensis* (0%) was not detected in either of the rainy seasons. The marked increase in the prevalence of *Falcaustra petrei* and *Rhabdochona* *congolensis* indicates that *Clarias anguillaris* is more heavily infested in the dry season. Regarding mean intensity (Figure 3B), the highest values were observed for *Falcaustra petrei* (19.18±1.8) and *Rhabdochona congolensis* (6±1.01) in January, corresponding to the long dry season. In contrast, the lowest values were recorded during the long rainy season, particularly for *Falcaustra petrei* (6.83±1.5) in March, whereas *Rhabdochona congolensis* was not observed in either of the rainy seasons. In this organ, *Falcaustra petrei* appeared as a secondary species, whereas *Rhabdochona congolensis* was recorded as a rare species.

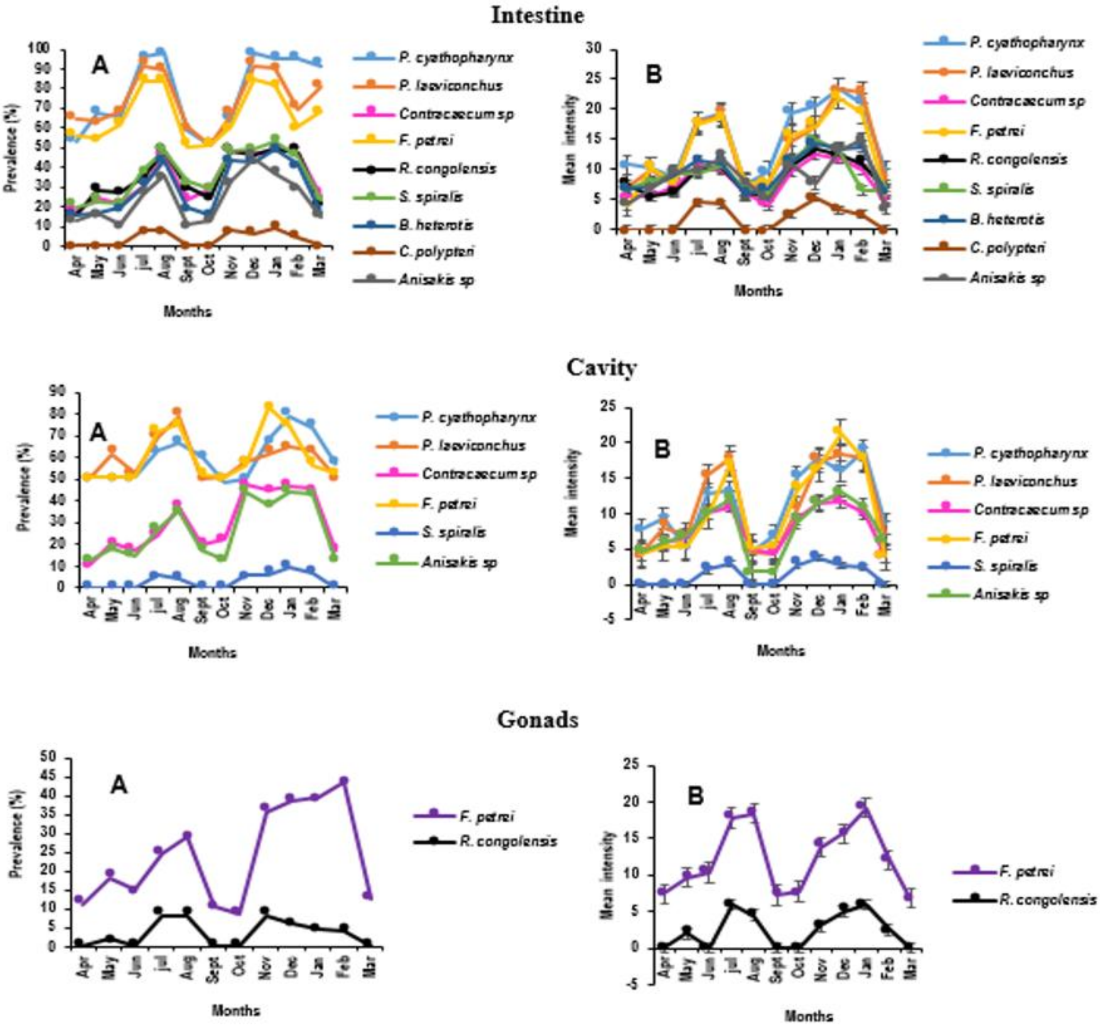

Figure 3: Seasonal variations in the Prevalence (A) and Mean intensity (B) of Nematodes P = *Paracamallanus cyathopharynx*, P = *Procamallanus laevionchus*, R = *Rhabdochona congolensis*, S = *Spiralis*, S = *Spirale*, B = *Brevimulticaecum heterotis*, C = *Camallanus polypterii*, *Anisakis* sp., F = *Falcaustra petrei* and *Contracaecum* sp. parasitic species in the intestinal cavity, general cavity and gonads of *Clarias anguillaris* sampled in the Bandama River.

Diversity of parasite communities in *Clarias anguillaris*

The overall diversity of the parasitic nematode community in *Clarias anguillaris* was assessed across seasons using species richness (SR), the Shannon–Weaver diversity index (H′), Simpson's diversity index (D), and Pielou's evenness index (E). The results revealed a marked seasonal variation in the structure of the parasite community (Table 1). Species richness was higher during the dry season, with a maximum of 9 nematode species recorded, compared to a minimum of 6 species in the rainy season. This fluctuation reflected an increased diversification of the parasite community during the dry season. In *C. anguillaris*, H′ values ranged from 2.52 bits per individual during the small rainy season to 3.32 bits per individual during the long dry season, indicating a concurrent increase in species richness and relative abundance during the dry period. Similarly, Simpson's diversity index showed high values regardless of the season, indicating a well-diversified parasite community. Values ranged from 0.75 during the long rainy season to 0.84 during the long dry season, confirming higher diversity in the dry season. Pielou's evenness index (E) indicated a relatively uniform distribution of individuals among nematode species throughout the seasons. Evenness values ranged from 0.71 during the small rainy season to 0.85 during the long dry season.

Table 1: Diversity indices of parasitic nematodes of Clarias anguillaris captured in the Bandama River at N'Denou

Diversity Indices	*SDS*	*LDS*	*SRS*	*LRS*
Specific richness	9	9	6	6
Shannon–Weaver Index	3.02	3.32	2.52	2.60
Simpson Index	0.82	0.84	0.77	0.75
Equitability	0.80	0.85	0.71	0.73

Note: SDS = Small Dry Season; LDS = Long Dry Season; SRS = Small Rainy Season; LRS = Long Rainy Season.

Impact of parasitism on the condition factor (K) of *Clarias anguillaris* according to season

Table 2 presents the seasonal variations in the condition factor (K) of *Clarias anguillaris* sampled from the Bandama River at N'Denou. During the dry season, parasitized fish exhibited a markedly lower condition factor (0.27 ± 0.01) compared to non-parasitized individuals (0.68 ± 0.02). This difference was statistically significant according to the Mann–Whitney test ($p = 0.01 < 0.05$), suggesting a deterioration in body condition associated with parasitism during this period. In the rainy season, a similar trend was observed, with a condition factor of 0.43 ± 0.01 in infected individuals compared to 0.77 ± 0.01 in uninfected fish. The Mann–Whitney test confirmed that this difference was also statistically significant ($p = 0.03 < 0.05$). Furthermore, a comparative analysis of parasitized fish between the two seasons revealed a significant increase in the condition factor during the rainy season relative to the dry season, with this variation being statistically supported ($p = 0.02 < 0.05$).

Table 2: Condition factor (K) (g/cm^3) of Clarias anguillaris infested and uninfested by parasitic nematodes sampled in the Bandama River (N'Denou)

Seasons	*Clarias anguillaris Status*	*Number of fish*	*Condition factor (g/cm^3)*	*p values*
Rainy Season	Examined	281	—	—
	Infested	185	0.43 ± 0.01	0.03
	Uninfested	96	0.77 ± 0.01	
Dry Season	Examined	279	—	—
	Infested	252	0.27 ± 0.01	0.01
	Uninfested	27	0.68 ± 0.02	

Note: The "Examined" rows do not have a condition-factor value or separate p-value in the original table, so these are represented by —.

Discussion

The examination of the gills, oesophagus, stomach, intestine, body cavity, and gonads of *Clarias anguillaris* collected from the Bandama River allowed the identification of nine nematode species. Previous studies by Kabré (1997) and Sinaré et al. (2021) reported 11 and 6 nematode species, respectively, in *C. anguillaris* in Burkina Faso. These differences in species richness may be attributed to the lotic nature of the river ecosystem (Azza et al., 2023). Indeed, lotic environments are often unstable due to flooding events and seasonal variations in water flow. Such disturbances can limit the occurrence of certain sensitive species and lead to changes in nematode community composition. Furthermore, the high occurrence of nematode species in the Bandama River may be related to their biological life cycles, particularly direct and indirect transmission modes (Blahoua and Adou, 2025). Indeed, species such as *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, and *Camallanus polypteri* exhibit indirect life cycles, requiring intermediate hosts for their development. In such cycles, larvae develop in copepods and other aquatic invertebrates before being ingested by *Clarias anguillaris*. Consequently, the abundance of these intermediate hosts in the environment promotes the multiplication, transmission, and persistence of these parasites within the ecosystem. Some species such as *Contracaecum* sp., *Anisakis* sp., and *Brevimulticaecum heterotis* may be present due to their broad range of intermediate and definitive hosts (Sinaré et al., 2021). These parasites involve piscivorous birds such as cormorants and pelicans as definitive hosts, while larval stages develop in fish, particularly catfish (Yanong, 2002). Regarding *Falcaustra petrei*, it may exhibit a simpler, sometimes direct life cycle, in which infection occurs through ingestion of eggs or larvae present in water or sediments. In this case, factors such as fish density and environmental conditions strongly influence transmission dynamics. Thus, the Bandama River provides suitable conditions for these parasites, including a stable aquatic environment, a high diversity of organisms acting as intermediate and definitive hosts, and an active food web. Their presence therefore reflects the adaptation of their biological cycles to this environment and their ability to complete all developmental stages therein, as previously noted by Tossavi et al. (2024).

In this study, the species *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Contracaecum* sp., *Falcaustra petrei*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, and *Anisakis* sp. showed higher infestation levels in *Clarias anguillaris* during the dry season. The high infestation rates observed in *C. anguillaris* may be explained by the increased availability of intermediate hosts, particularly zooplankton (N'Guessan et al., 2010 ; Monney et al., 2015). Indeed, the reduction in water volume during this period leads to nutrient concentration, which promotes phytoplankton proliferation. This, in turn, supports zooplankton growth, resulting in higher abundance of these organisms. Zooplankton then serve as intermediate hosts for parasite larval stages, facilitating their development. *Clarias anguillaris* becomes infected through the ingestion of these infected zooplankton during feeding. In addition, the high infestation levels may also be related to water pollution and poor water quality in the river. The reduction in water flow leads to the concentration of pollutants (Abdel-Gaber et al., 2015), including silt particles, residues of agrochemical products from surrounding agricultural areas, and decomposing organic matter. This accumulation severely degrades the aquatic environment, induces physiological stress in fish, and weakens their immune system. Moreover, these conditions favor the proliferation of pathogens and infective stages of parasites, thereby increasing the vulnerability of *Clarias anguillaris*. Furthermore, the absence of strong water currents during the dry season reduces the dispersion of parasite eggs and larvae, increasing their concentration in the environment and the likelihood of encountering host fish. However, the lower infestation levels observed in *Clarias anguillaris* during the rainy season in the Bandama River can be explained by major environmental changes, particularly flooding. Flooding modifies benthic habitats and disperses intermediate hosts, thereby disrupting the life cycles of many parasites. Increased spatial dispersion of *Clarias anguillaris* populations in flooded areas reduces host density and contact rates, consequently decreasing both direct and indirect transmission. Finally, improved physico-chemical water conditions, including increased oxygenation and reduced concentrations of stagnant organic matter, create less favorable conditions for parasite survival and proliferation. These results are consistent with those reported by Mashaly (2014).

The analysis of seasonal variations indicates a low amplitude in fluctuations of species richness within parasite communities over the annual cycle. The differences observed between seasons can be explained by the influence of environmental conditions on the transmission dynamics of nematode parasites of *Clarias anguillaris*. During the dry season, water concentration enhances contact between parasites and their hosts, leading to an increase in observed diversity. In contrast, during the rainy season, the dispersion of intermediate hosts reduces encounter opportunities, resulting in a slight decrease in the number of detected species.

The Shannon–Weaver and Simpson diversity indices recorded in host species were above average, indicating high parasitic diversity. This can be attributed to seasonal variations in environmental conditions, which modify physicochemical parameters and host–parasite dynamics (Kennedy, 2009 ; Shocket et al., 2018). These changes alternate between host dispersion and concentration, thereby promoting both transmission and coexistence of different nematode species throughout the seasons. Nematode species of *Clarias anguillaris* exhibited evenness values close to 1 across all seasons, indicating a relatively homogeneous distribution. This seasonal stability may be explained by the influence of the upstream dam on the Bandama River, which strongly modifies the ecological dynamics of the system. By regulating river discharge, the dam reduces natural hydrological contrasts between the rainy and dry seasons. Flood peaks are attenuated and low-flow periods are less severe, limiting the seasonal changes that typically drive strong variations in intermediate host availability, larval dispersion, and habitat connectivity. Consequently, nematode transmission conditions remain relatively constant throughout the year.

In this study, the condition factor (K) values recorded for both infested and non-infested *Clarias anguillaris* were consistently below the reference value (1) across seasons, indicating an overall suboptimal physiological status of the population. However, clear differences were observed according to parasite status and season. In the dry season, infested fish exhibited the lowest condition factor values. This marked decline can be explained by the combined effects of poor water quality and parasitic infection. As reported by El Tantawy et al. (2023), the degradation of water quality acts as a major stressor for aquatic organisms. Under such stressful conditions, fish become more susceptible to parasitic infections, while their general physiological condition deteriorates. The association between environmental stress and parasitism therefore contributes significantly to the reduction of body condition in *C. anguillaris*. Moreover, the low condition factor observed during the dry season may also be linked to reduced dissolved oxygen levels, which limit fish respiratory efficiency. In parasitized individuals, this constraint is exacerbated, as gill- or blood-inhabiting parasites further impair respiratory and energetic functions. In addition, the increase in organic matter during this period enhances microbial decomposition processes, leading to higher oxygen consumption in the environment and intensifying hypoxic conditions. Consequently, infected fish must expend more energy to meet their oxygen demands, resulting in fatigue, reduced activity, weight loss, and overall physiological impairment (Akinsanya & Otubanjo, 2006). In contrast, during the rainy season, condition factor values of parasitized fish were slightly higher, although still below 1. This improvement is mainly attributed to favorable ecological changes, particularly increased food availability and habitat expansion. Rainfall leads to the flooding of surrounding areas, which enhances the availability of diverse food resources such as insects, larvae, plankton, and organic detritus. This abundance of food allows fish to accumulate energy reserves, mainly in the form of muscle mass, resulting in a relative improvement in body weight and condition factor. Furthermore, flood events expand aquatic habitats and temporarily reduce intra- and interspecific competition. Fish therefore gain access to a broader range of feeding areas and resources, which supports growth and improves physiological condition. Under these conditions, although parasites continue to exert an energetic cost on their hosts, their negative effects are partly offset by increased resource availability. Overall, these findings indicate that environmental conditions and parasitism jointly influence the condition factor of *Clarias anguillaris*, with the most pronounced negative effects observed during the dry season. These results are consistent with those reported by Blahoua and Adou (2025).

Conclusion

This study conducted on *Clarias anguillaris* in the Bandama River at N'Denou highlighted a high diversity of parasitic nematodes, as well as the significant influence of environmental and seasonal factors on their dynamics. A total of nine nematode species, namely *Paracamallanus cyathopharynx*, *Procamallanus laeviconchus*, *Contracaecum sp*., *Falcaustra petrei*, *Rhabdochona congolensis*, *Spirocamallanus spiralis*, *Brevimulticaecum heterotis*, *Camallanus polypteri*, and *Anisakis sp*., were identified, confirming that this aquatic environment hosts a rich parasitic fauna. This species richness is strongly influenced by the lotic nature of the river, the availability of intermediate and definitive hosts, and the diversity of parasite life cycles.

Seasonal analysis showed higher infestation levels during the dry season, mainly due to host concentration, deterioration of water quality, decreased dissolved oxygen, and reduced river flow. In contrast, the rainy season is characterized by water dilution, dispersion of intermediate hosts, and improved physicochemical conditions, which generally limit parasite transmission.

Diversity indices, which are Shannon, Simpson, and evenness, indicated high and relatively stable parasitic diversity throughout the year, reflecting a balanced coexistence of species despite seasonal variations. Finally, the condition factor analysis revealed an overall poor physiological state of the fish, more pronounced in parasitized individuals and during the dry season. However, a relative improvement was observed in the rainy season, which is linked to increased food availability and habitat expansion, factors that partially offset the negative impact of parasites.

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