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Research Article

DIVERSITY OF GILL PARASITIC COPEPODS AND PARAMETERS INFLUENCE ON INFESTATION IN NILE TILAPIA (*Oreochromis niloticus*) FROM THE TAABO MAN-MADE LAKE (COTE D'IVOIRE)

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ABSTRACT

Oreochromis niloticus fish has long served as an essential source of animal protein for local populations, contributing not only to food security but also to job creation. However, a decline in its stock has been observed in recent times. Sustainable management of this species is therefore crucial in the face of health threats, including infestations by parasitic copepods which negatively affect the appearance and reduced production of species of economically important fish, both from the wild and fish farms. During May 2023 to April 2024, the gill parasitic copepod fauna of 1180 specimens of *O. niloticus* were captured in the both Ahondo and Courandjourou stations of Taabo hydroelectric man-made lake was investigated in order to study the diversity of these species and assess the impact of abiotic and biotic factors on the infestation of this fish. Once the fish had been caught, standard methods for the study of gill parasitic copepods were used. Three parasite species were identified: *Lamproglena monodi*, *Lernaea barnimiana* and *Ergasilus latus*. The calculated diversity indices reflect a fairly well-structured parasitic community. The study revealed a significant variation in fish infestation according to sampling stations, seasons and host sex. In addition, it revealed that all fish examined had a condition factor of less than 1 (K<1). However, there was significant difference between the condition factor of infested and uninfested fish. These informations could be taken into consideration when implementing health management practices in fish culturing programs or to develop control strategies against these pathogens in order to enhance fish production in this environment.

Keywords: *Oreochromis niloticus*, Gill parasitic copepod, Infestation, Taabo man made lake, Côte d'Ivoire.

INTRODUCTION

Commonly referred to as freshwater carp, *Oreochromis niloticus* (Linnaeus, 1758) is a fish species of African origin naturally distributed across the Niger, Volta, Senegal, and Congo river basins (Philippart and Ruwet, 1982). Widely used in aquaculture across various parts of the world-including Asia, Europe, and Africa-this species has proven to be highly successful in fish farming (El-Sayed and Kawanna, 2004). Rich in protein with high biological value, *O. niloticus* plays a vital role in the nutrition of populations in many countries (FAO, 2004). Despite its importance, this fish is frequently infested by parasitic copepods (Sèdogbo *et al*., 2019; Zannou *et al*., 2019). These parasites are metazoans that develop at the expense of their host and are characterized by a heteroxenous life cycle (Kabata, 1979). Copepods occupy a unique position among aquatic parasites due to their remarkable adaptability to a wide range of hosts (Raibaut, 1996). They are known to exert pathogenic effects on freshwater fish (Piasecki *et al*., 2004); while some species cause gill tissue proliferation, others are responsible for large-scale mortalities in fish populations (Johnson *et al*., 2004; Meddour, 2009). According to Ramdane and Trilles (2009), these parasites contribute to significant weight loss and weakening of fish populations, ultimately reducing aquaculture productivity. The Nile tilapia, which is

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widespread in freshwater environments, can be subject to such problems. Therefore, in light of the pathogenic effects associated with copepods, a better understanding of the infestation patterns within its populations is essential. Some studies have been made on parasitic copopods affecting *O. niloticus*. Among relevant studies are those conducted by Sèdogbo *et al*. (2019) and Zannou *et al*. (2019) in Benin, by M'bareck *et al*. (2019) in Mauritania, and by Boualleg *et al*. (2010) in Algeria. In Côte d'Ivoire, the only available data on these pathogenic organisms are those of Blahoua *et al*. (2020) and Adou *et al*. (2021), which focused respectively on the parasitic fauna of *Oreochromis niloticus* and *Sarotherodon melanotheron* in Lake Ayamé and in Ebrié Lagoon. However, to date, no study has been conducted on parasitic copepods of *Oreochromis niloticus* in the Taabo man-made lake. This is particularly concerning, as the lake is increasingly subjected to anthropogenic pressures leading to water quality degradation and these conditions that may favor the proliferation of these parasites. Furthermore, a marked decline in both the size and population of freshwater carp, a species highly valued by local communities, has been observed. This decline could partly be attributed to the deleterious effects of parasitic copepods on fish condition in this environment. Considering the economic and nutritional significance of *Oreochromis niloticus* for local populations, and the fact that these parasites constitute a serious constraint to the sustainable large-scale production of this species, the present study aimed to investigate certain aspects of gill parasitic infestation in Nile Tilapia, *Oreochromis niloticus* from the Taabo man-made lake in order to generate sufficient data to mitigate the observed catastrophic losses and enhance aquaculture productivity in this environment.

MATERIALS AND METHODS

Study area

Constructed on the main branch of the Bandama River, the Taabo hydroelectric reservoir (Figure 1) is located between 5°42' and 5°90' West longitude and 6°10' and 6°56' North latitude. It lies approximately 110 km downstream from the confluence of the White Bandama and the Red Bandama rivers. It has a catchment area of about 58.700 km² and an average annual discharge of approximately 128.7 m³/s. The lake covers an area of 69 km² (Kouassi, 2007; Aliko *et al*., 2010). According to Brou *et al*. (2005), the Taabo hydroelectric reservoir is influenced by a transitional tropical climate characterized by four seasons: two rainy seasons (March to June and September to October) and two dry seasons (November to February and July to August). Taking into account the accessibility and availability of fishery resources, two sampling stations were selected on Lake Taabo. There were Ahondo and Courandjourou stations. Located between 6°17' N and 6°47' N then 5°42" W and 5°60' W, the Ahondo station is characterized by a dense presence of aquatic vegetation, particularly water hyacinths, covering an average of 78% of the water surface. The substrate is predominantly sandy, interspersed with mud and occasional submerged dead tree trunks. The station is bordered by yam and cocoa plantations, as well as forested areas. The average water depth at this sampling site is approximately 6 m. Situated between 6° 13'47" N and 6° 17'N then 5° 6'57" W and 5° 60'W, the Courandjourou station exhibits a lower vegetation cover, estimated at around 15%. This station is also bordered by cocoa and plantain banana plantations. The substrate is primarily composed of mud, white clay, and scattered submerged wooden branches, making navigation difficult. The average water depth at this site is approximately 7.25 m.

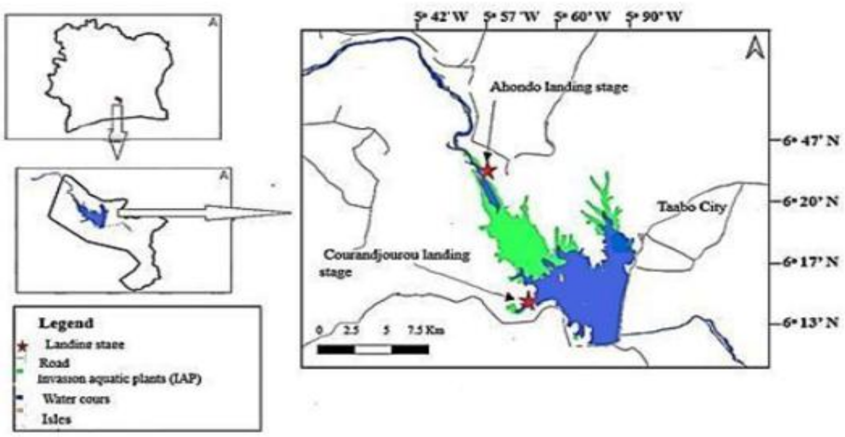

Figure 1. Map of Taabo man made lake and the sampling stations.

Sampling fish

The fish examined in the present study were obtained from experimental fishing conducted using nets of various mesh sizes from May 2023 to April 2024 in the Taabo man-made Lake. One thousand-one hundred eighty individuals of *Oreochromis niloticus* were captured, with 590 specimens collected from each of the Ahondo and Courandjourou stations. After capture, individuals of *Oreochromis niloticus* were identified following the recommendations of Teugels and Thys van den Audenaerde (2003). The standard and total lengths of each fish were measured using an ichthyometer. Then, they were weighed with a precision balance accurate to 1 g. The fish sex was identified by physical observation of the urogenital papillae in males, as well as round and reddish in the matured females. These were later confirmed after dissection by visual observation of the testes in males and ovaries in the females. The gills were carefully dissected and labeled according to each corresponding specimen. They were kept on ice until transported to the laboratory, where they were stored in a refrigerator.

Survey, coloration and identification of the parasites

The preserved gills were thawed, and the gill arches of the fish were rinsed using a wash bottle and tap water. Parasitic copepods were collected under a binocular magnifying lens. Once harvested, the specimens were fixed by immersion in 10% formalin for 24 hours, then mounted in Canada balsam using a stereomicroscope and a compound light microscope. Identification of the parasitic copepods species was based on the examination of morphological and anatomical characteristics as described by Yamaguti (1963).

Epidemiological approach and Diversity indices

Parasitological indices such as prevalence, mean intensity and abundance, as defined by Bush *et al*. (1997) were calculated. The Shannon-Weaver diversity index, the Evenness index and the Simpson's are key metrics in ecological studies used to assess the diversity and distribution of species and the dominance within a community. These indices are valuable for understanding the ecological balance, the stability of an ecosystem, and the impacts of environmental changes or human interventions on species populations. They help in evaluating the health of the ecosystem, biodiversity conservation efforts, and can inform management strategies for sustainable resource use. The Shannon and Weaver index (1963) (H') was used to quantify the heterogeneity of biodiversity in the environment. It takes into account both the number of species and the number of individuals of each species. It can consider all individuals randomly sampled from an indefinitely large population (Piélou, 1975). When H' is minimal (H' = 0), all individuals in the community belong to a single species. The index is maximal (around 5) when all individuals are evenly distributed among the species (Frontier, 1983). It is obtained by the following formula (Magurran, 1988):

$$H' = -\Sigma\ ((Ni\ /N) \times \log2\ (Ni\ /N))$$

The Evenness index (E) reflects the distribution of species within the sample. It is the ratio between the actual diversity and the maximum diversity that the community could achieve (H'max = log2 S) when all species have the same abundance (Hill, 1973). It is obtained by the following formula:

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

with:
- H': Shannon-Weaver diversity index,
- H'max : log2 S,
- S: specific richness

The Simpson's diversity index is sensitive to the abundances of the most common species. It is one of the measures of dominance. It provides the probability that two randomly selected individuals from a large population will belong to different species (Simpson, 1949). The Simpson's Diversity Index ranges from 0 to 1. Maximum diversity is represented by a value of 1, while minimum diversity corresponds to a value of zero. It is also important to note that this index gives more weight to abundant species than to rare ones. In fact, adding rare species to the community has little to no effect on the overall value of the diversity index. According to Magurran (1988), the formula is as follows:

$$S = 1-D$$
with: - $D = \Sigma pi^2$

- **Pi** is the proportion of individuals belonging to species i.

Condition Factor (K)

Fulton's condition factor (K) assumes that fish weight is proportional to the cube of its length and was used to assess the general health status of fish at both individual and population levels. The total length, standard length, and body mass of all individuals were measured. The allometric equation, where the exponent *b* is a constant, was used to compare the health index across different fish categories:

$K = (W \times 100) / L^b$ (Le Cren, 1951)
Where:
K = Condition factor
W = Fish weight in grams
L = Total length of the fish in centimeters

Fulton's condition factor is multiplied by 100 to bring the values closer to 1. A value of 1 indicates a normal condition, a value greater than 1 indicates a well-fed or "fat" fish, and a value less than 1 indicates a thin or undernourished fish. This morphometric index is based on the assumption that, for a given length, a heavier fish is in better condition.

Statistical analysis

The difference in parasite prevalence was tested by using the Chi-square (χ^2). It was used to compare two or more proportions, while the Kruskal-Wallis test was applied to compare parasite intensities among more than two samples. The difference in parasite intensities between two different samples was tested by using the Mann-Whitney test. The degree of security for statistical analyses was 95%. These statistical analyses were performed using the STATISTICA version 7.1.

RESULTS AND DISCUSSION

The observation of *Oreochromis niloticus*' gills from the Taabo reservoir lake led to the collection of 8.751 individuals of parasitic copepods. Morphological criteria used for identification revealed the presence of three species of parasitic copepods at each of the two study stations. The parasitic copepods species are *Lamproglena monodi* Capart, 1944, *Lernaea barnimiana* (Hartmann, 1865) and *Ergasilus latus* (Haller, 1856). The values of diversity indices calculated of Shannon-Weaver (H'), Evenness (E) and Simpson's index (S) are presented in Table 1. Analysis of this table indicated that these values indices were above average (H' > 2.5, E > 0.5 and S > 0.5) in both study stations. At the Ahondo station, the Shannon-Weaver index (H' = 3.4 bits/ind.) and the Evenness index (E = 0.82) were slightly higher than those observed at the Courandjourou station, where the Simpson index (S = 0.93) was marginally greater.

Table1. Diversity indices of the parasitic population of *Oreochromis niloticus* at the Ahondo and Courandjourou stations in the Taabo man-made lake.

Stations	Number of Copepode parasite species	Shannon and Weaver Index (H')	Equitability Index (E)	Simpson index (D)
Ahondo	3	3.4	0.82	0.91
Courandjourou	3	2.9	0.85	0.93

Table 2. Spatial variation of Prevalence (P), Mean Intensity (MI) and Abundance (A) of Copepods parasitic of *Oreochromis niloticus* from the sampling stations in the Taabo man-made lake.

Stations	Parasite species	Number of fish examined	Number of fish infested	P (%)	IM±SE	A
Ahondo	*Lamproglena monodi*	590	125	21.19	19.85±1.6	0.21
	Lernea. barnimiana	590	102	17.29	24.31±0.5	0.17
	Ergasilus latus	590	111	18.81	22.15±0.8	0.19
Courandjourou	*Lamproglena monodi*	590	102	17.29	12.14±0.9	0.17
	Lernea barnimiana	590	13	2.2	2.38±0.4	0.02
	Ergasilus latus	590	17	2.88	3.65±0.6	0.03

Table 2 illustrates the variation in epidemiological indices of parasitic copepods collected from the gills of *Oreochromis niloticus* at the Courandjourou and Ahondo sampling stations in the Taabo reservoir. With prevalence values ranging between 10% and 50%, the parasitic species *Lamproglena monodi*, *Ergasilus latus* and *Lernaea barnimiana* were considered secondary species at the Ahondo station. In contrast, except for *Lamproglena monodi*, which was also categorized as a secondary species with prevalence values below 10%, the other two parasites were classified as rare species within the parasitic community of this fish at the Courandjourou station. Furthermore, high prevalence rates of *Lamproglena monodi* (21.19%), *Ergasilus latus* (18.81%) and *Lernaea barnimiana* (17.29%) were recorded at the Ahondo station. The observed differences in prevalence between these three gill-infesting copepod species in the two sampling stations were statistically significant (Chi-square test, $p < 0.05$). Regarding mean intensities, the highest values for *Lamproglena monodi* (24.31 ± 0.5), *Lernaea barnimiana* (19.85 ± 1.6) and *Ergasilus latus* (22.15 ± 0.8) were observed at the Ahondo station. The corresponding abundance values recorded at the same station were 0.21, 0.17, and 0.19, respectively. The Mann-Whitney tests performed on parasitic intensity and abundance data revealed statistically significant differences between the two study stations ($p < 0.05$).

The average monthly variation of the parasitic indices of *Lamproglena monodi*, *Ergasilus latus* and *Lernaea barnimiana*, copepod parasites of *Oreochromis niloticus* captured at the Ahondo station, is illustrated in Figure 2. Analysis of this figure showed that the highest prevalence values were recorded for *L. monodi* (27.66%) and *E. latus* (21.28%) in October, and for *L. barnimiana* (27.08%) in June, corresponding respectively to the short and long rainy seasons. In contrast, the lowest prevalence values were observed in February for *Lamproglena monodi* (13.64%) and *Lernaea barnimiana* (11.36%), and in January for *Ergasilus latus* (11.76%), corresponding to the long dry season. The Chi-square test performed on the prevalence of the copepod species (*Lamproglena monodi*, *Lernaea barnimiana*, and *Ergasilus latus*) revealed significant differences between seasons ($p < 0.05$). Concerning mean intensity (Figure 2), high values were recorded in October-during the short rainy season-for *Lamproglena monodi* (28.31 ± 1.2), *Ergasilus latus* (37 ± 0.6), and *Lernaea barnimiana* (31.17 ± 0.9). However, low mean intensity values were recorded in February for all three species, during the long dry season. These values were 7.6 ± 0.3, 9 ± 1.1, and 8 ± 0.4, respectively. Similarly, high values of parasite abundance were recorded in October (Figure 2), with 7.83 for *Lamproglena monodi*, 7.87 for *Ergasilus latus*, and 7.96 for *Lernaea barnimiana*, corresponding to the short rainy season. Conversely, the lowest abundance values were observed in February for *Lamproglena monodi* (1.22), *Ergasilus latus* (1.2) and *Lernaea barnimiana* (1.18), during the long dry season. The Mann-Whitney (U) test applied on parasitic intensities and abundances showed that the infestation of *Oreochromis niloticus* by copepods varied significantly with the seasons ($p < 0.05$). The average monthly variations in epidemiological indices of the three copepod parasites of *Oreochromis niloticus* at the Courandjourou station are shown in Figure 3. High prevalence values were observed in October (short rainy season) for *Lamproglena monodi* (21.28%), *Lernaea barnimiana* (4.25%), and *Ergasilus latus* (8.51%). In contrast, the lowest prevalence values were recorded in August (short dry season) for *Lamproglena monodi* (13.72%), *Lernaea barnimiana* (1.96%), and *Ergasilus latus* (1.96%). Significant seasonal differences in prevalence among the three species were confirmed by the Chi-square test ($p < 0.05$). Concerning mean parasitic intensity, elevated values were recorded in October for *Lamproglena monodi* (16.3 ± 2.1), *Lernaea barnimiana* (5 ± 1.6), and *Ergasilus latus* (4.5 ± 0.3), corresponding to the short rainy season. The lowest intensity value was observed for *Lamproglena monodi* (5.14 ± 1.1) in August (short dry season). The other two copepod species were not collected during the period from November to December, which corresponds to the long dry season. The pattern of parasitic abundance in this fish is similar that of the mean intensity (Figure 3). Maximum values were recorded in October for *Lamproglena monodi* (3.4), *Lernaea barnimiana* (0.21), and *Ergasilus latus* (0.38), all during the short rainy season. In contrast, the host fish was not infested by the first species in December, nor by the other two species in February, periods corresponding to the long dry season. The Mann-Whitney (U) test applied on parasitic intensities and abundances revealed a significant seasonal difference ($p < 0.05$) in the infestation of *Oreochromis niloticus* by parasitic copepods.

The analysis of epidemiological indices according to the sex of *Oreochromis niloticus* captured at the Ahondo and Courandjourou stations is summarized in Table 3. In both stations, 590 *Oreochromis niloticus* fish individuals were examined. At the Ahondo station, the sample consisted of 297 male and 293 female individuals, whereas at Courandjourou, 290 males and 300 females were examined. At the Ahondo station, analysis of the table showed that the highest prevalence values for *Lamproglena monodi* (31.40%) and *Lernaea barnimiana* (26.28%) were recorded in female hosts, while *Ergasilus latus* exhibited the highest prevalence (28.95%) in male hosts. The observed differences in prevalence for *Lamproglena monodi* and *Lernaea barnimiana* in female fish, and for *Ergasilus latus* in male fish, were statistically significant (Chi-square test, $p < 0.05$). Regarding mean intensity and abundance, the highest values (25.60 ± 1.4 and 1.19, respectively) were recorded for *Ergasilus latus* in male fish. In contrast, elevated mean intensity values for the parasitic copepods *Lamproglena monodi* (23.09 ± 2.1) and *Lernaea barnimiana* (27.22 ± 3.1) were observed in female hosts, with corresponding abundance values of 7.25 and 7.15, respectively. The Mann-Whitney test applied to parasitic intensity and abundance revealed that male hosts harbored significantly more *Ergasilus latus* copepods than female hosts. However, female individuals were significantly more infested by *Lamproglena monodi* and *Lernaea barnimiana* ($p < 0.05$). The analysis of this table also indicated that the prevalence values for the parasites

Lamproglena monodi (27.2%) and *Ergasilus latus* (4.76%) were higher in male hosts, whereas *Lernaea barnimiana* showed a higher prevalence (4.29%) in female fish. The Chi-square test revealed that male hosts harbored more *Lamproglena monodi* and *Ergasilus latus* copepods than female hosts, while the latter were more infested with *Lernaea barnimiana*. The highest mean intensity and abundance values were recorded in male fish for *Lamproglena monodi* (14.4 ± 1.5 and 3.92, respectively) and for *Ergasilus latus* (4 ± 1.2 and 0.19, respectively). In contrast, a higher mean intensity for *Lernaea barnimiana* (2.38 ± 0.6) was observed in female fish, with a corresponding abundance value of 0.10. The Mann-Whitney test applied to parasitic intensity and abundance revealed a significant difference in the infestation of this fish species by the copepods *Lamproglena monodi*, *Lernaea barnimiana* and *Ergasilus latus* ($p < 0.05$).

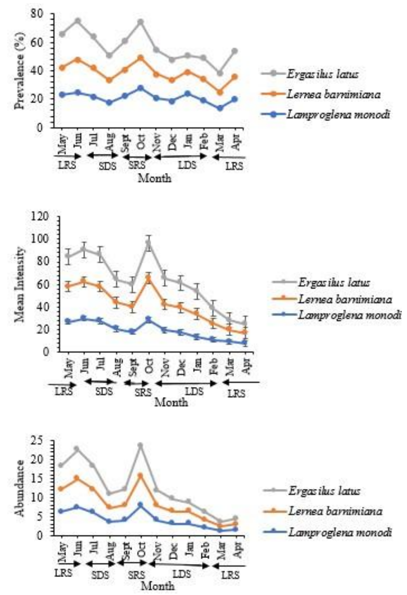

Figure 3. Temporal variation of the Prevalence, Mean Intensity and Abundance of gill copepod parasites from *Oreochromis niloticus* in the Ahondo station of the Taabo man made lake.
LRS: long rainy season; SDS: small dry season, SRS: small rainy season; LDS: long dry season

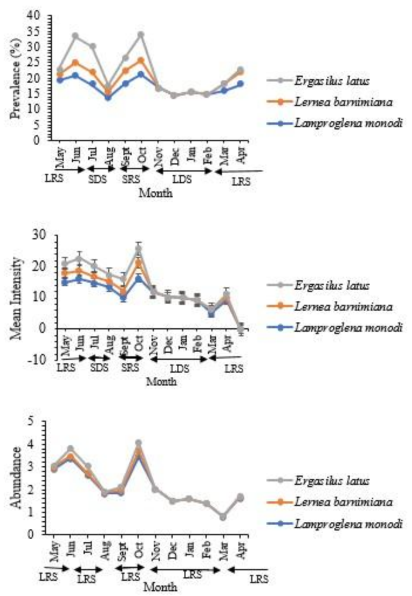

Figure 4. Temporal variation of the Prevalence, Mean Intensity and Abundance of gill copepod parasites from *Oreochromis niloticus* in the Courandjourou station of the Taabo man made lake.
LRS: long rainy season; SDS: small dry season, SRS: small rainy season; LDS: long dry season

Table 3. Prevalence (P), mean intensity (MI) and abundance (A) of parasitic copepods according to the sex of *Oreochromis niloticus* sampled in the Taabo man-made lake.

Ahondo Station								
	Males (n=297)				Females (n=293)			
Copepode species	Fish infested	P (%)	IM±SE	A	Fish infested	P (%)	IM	A
Lamproglena monodi	33	11.11	10.82±1.2	1.2	92	31.40	23.09±2.1	7.25
Lernea barnimiana	25	41	15.36±2.1	1.29	77	26.28	27.22±3.1	7.15
Ergasilus latus	86	28.95	25.60±1.4	1.43	25	8.53	10.28±1.6	0.87

Courandjourou Station								
	Males (n=290)				Females (n=300)			
Copepode species	Fish infested	P (%)	IM±SE	A	Fish infested	P (%)	IM±SE	A
Lamproglena monodi	80	27.21	14.4±1.5	3.92	12	3.96	7.17±1.2.	0.28
Lernea barnimiana	0	0	0	0	13	4.29	2.38±0.6	0.10
Ergasilus latus	14	4.76	4±1.2	0.19	3	0.99	0.82±0.2	0.02

The mean condition factor (K) values for *Oreochromis niloticus* either infested or uninfested by parasitic copepods at the Ahondo and Courandjourou stations of the Taabo man made lake are presented in Table 4. Analysis of this table showed that the mean condition factor at the Ahondo station was 0.44 ± 0.01 g/cm³ for infested fish and 0.76 ± 0.1 g/cm³ for uninfested fish. At the Courandjourou station, these values were 0.57 ± 0.02 g/cm³ for infested individuals and 0.83 ± 0.01 g/cm³ for uninfested ones. The Mann-Whitney test revealed a statistically significant difference ($p < 0.05$) between the mean condition factor values of infested and uninfested fish at each station. Furthermore, the test also highlighted that infested fish from the Ahondo station were significantly thinner ($p < 0.05$).

Table 4. Condition factor (K) of infected and uninfected *Oreochromis niloticus* fish in Ahondo and Courandjourou stations in the Taabo man-made lake

Stations		Number of fish	Condition factor
Ahondo	Fish examined	590	Condition factor (K) (g/cm³)
	Infested Fish	125	0.44± 0.01
	uninfected fish	465	0.76 ± 0.1
Courandjourou	Fish examined	590	Condition factor (K) (g/cm³)
	Infested Fish	102	0.57 ± 0.02
	uninfected fish	488	0.83 ± 0.01

DISCUSSION

The study of parasitic copepods in *Oreochromis niloticus* fish from the Taabo man-made Lake allowed to the identification of three parasite species: *Lamproglena monodi*, *Lernaea barnimiana* and *Ergasilus latus*. Parasite richness was found to be three species at both the Ahondo and Courandjourou sampling stations. Authors such as Sèdogbo *et al*. (2019) and Zannou *et al*. (2019) had reported the presence of one to two species of parasitic copepods on the same fish species in the upper delta of the Ouémé River in southern Benin. However, Jamila *et al*. (2021) and M'bareck *et al*. (2019) each recorded only a single species of parasitic copepod on *Oreochromis niloticus* in aquaculture farms in El-Abassa, Egypt, and the

Senegal River in Mauritania, respectively. It is well established that various factors can directly or indirectly influence the variation in parasite richness, as highlighted by authors such as Sasal *et al*. (1999) and El-Seify *et al*. (2011). These include the sampling effort, host life traits, size, behavior, habitat and the phylogeny of both hosts and parasites. The observed parasite richness could be attributed to habitat differences. Indeed, it's well known that each zone possesses specific ecological conditions that enable it to harbor distinct groups of parasite species in terms of both composition and abundance. The identical number of gill-infesting copepod species recorded at Ahondo and Courandjourou suggests that these parasite species are cosmopolitan and have adapted to the varying ecological conditions of the Taabo man-made lake.

In this present study, the Shannon-Weaver and Simpson indices recorded in the host species were above average. Parasite diversity is therefore considered high, particularly in the Ahondo station. This could be linked to the biotope being more productive, as ecosystems with high faunal density are conducive to the completion of parasitic life cycles, as noted by Ternengo (2004). According to Rohde *et al*. (1995) and Esch *et al*. (1990), variations in parasite abundance relative to their life cycles are generally influenced as much by the host's environment as by its physiology. The findings of the present study suggest that the different life stages of parasitic copepods find more favorable conditions for development at the Ahondo station compared to Courandjourou one. Moreover, equitability values above 0.6 indicate a homogeneous distribution of parasite individuals within their host population.

Fish from the Ahondo station exhibited the highest levels of infestation by parasitic copepods**.** It could be attributed by the fact that parasitic copepods, such as those from the genera *Ergasilus* and *Lernaea* (anchor worms), possess life cycles that are highly sensitive to the physicochemical conditions of their aquatic environment. Eutrophication in this station can significantly enhance their development, reproduction and transmission. Indeed, in eutrophic environments, there is a marked increase in primary production (algae and phytoplankton), which sustains zooplankton populations and leads to an abundance of trophic resources**.** This trophic enrichment often results in fish overpopulation, particularly tolerant species such as tilapias (*Oreochromis spp.*). The high fish density, combined with a weakened immune system due to environmental stress, and the proliferation of invasive aquatic vegetation on which free-swimming larval stages of copepods may attach collectively facilitate the direct transmission of these larvae or parasitic copepods to fish hosts, thereby explaining the high infestation levels frequently observed in such environments.

This study also revealed that *Oreochromis niloticus* individuals fish were more heavily infested by *Lamproglena monodi*, *Lernaea barnimiana* and *Ergasilus latus* during the rainy season. Similar results were previously reported by other authors studying parasitic copepods of the same or closely related fish species. For instance, Abdel-Gaber *et al*. (2017) in Egypt observed the highest levels of fish infestation during the rainy season. According to Austin and Avenat-Oldewage (2009), parasitic copepods attach to their hosts during the rainy season, and their ovaries become visible. The fertilized eggs are stored in egg sacs attached to the body and begin to hatch during the same season. A similar pattern was observed by Anvarifar *et al*. (2014), who reported high infestation rates of *Capoeta gracilis* by the copepod *Tracheliastes polycolpus* during the rainy season. In the current study, several reasons can explain the high levels of fish infestation during the rainy seasons. At first, it could be linked to a compromised immune system in fish during this period. In fact, during this time of year, water quality in the lake is significantly degraded due to runoff from various anthropogenic activities, thereby making aquatic organisms in general and fish in particular more vulnerable to elevated levels of parasitic infestation, as also noted by Kemp and Spotila (1997). Another possible explanation for the high level of fish infestation is that during the rainy season, the aquatic environment becomes richer in nutrients. As a result, fish actively move in search of food, which increases their exposure to parasitic infestation. The last possible explanation is the fact that, it has also been demonstrated that during the dry seasons, elevated water temperatures can lead to increased mortality of parasites in the aquatic environment.

The study of parasitism in relation to the host fish sex revealed a differential infestation pattern. The gills of male fish were the most frequently inhabited by *Ergasilus latus*, which may be attributed to the active foraging behavior exhibited by males. Indeed, in their search for food, these fish explore a wide range of habitats, increasing their exposure to parasitic infestation. This result may also be explained by Poulin's hypothesis (2006), which posits that the energy investment required for testosterone synthesis weakens the immune system in males, making them more susceptible to parasitic infection than females. Additionally, the gills of female fish were the most heavily infested by *Lamproglena monodi* and *Lernaea barnimiana*. Similar findings were reported by Boucenna *et al*. (2018), who observed infestation of *Luciobarbus callensis* by the parasitic copepods *Ergasilus*, *Neoergasilus* and *Lernaea* in the Foum El Khanga Dam in Algeria. In the present study, the high infestation rate observed in female fish may be due to their appearance and sedentary behavior during the reproductive period. During this time, some females undergo morphological changes that offer a larger surface area for parasite colonization. Furthermore, the reduced activity and increased sedentary behavior during this reproductive phase could facilitate the establishment of parasites on the host, thereby contributing to the observed high infestation levels.

The condition factor (K) reflects the physiological state of a fish in relation to its well-being and is frequently used to assess the effects of biotic and abiotic factors on the health or general welfare of a fish population (Oso and Iwalave, 2016). In the present study, the average condition factor calculated for the sampled fish was below one ($K < 1$), indicating poor health and signs of emaciation. According to Oso and Iwalave, 2016) and Ajibare *et al*. (2020), factors such as age, stress, sex, food availability, feeding activity, nutritional status, gonadal activity, season, weight variations, maturity stage, and various water quality parameters can influence the condition factor in fish. In this study, the low condition factor observed may be attributed to stress and the degradation of water quality in the Taabo dam lake. Indeed, various human activities are carried out in and around the lake, including agriculture, laundry, fishing, and especially artisanal gold mining. All these anthropogenic pressures severely impair the water quality of the lake and, as a consequence, negatively impact the body condition of the fish. At both study stations, the average condition factor for uninfested fish was significantly higher than that of infested individuals. However, these values remained lowest at the Ahondo station. This result may be explained by the impact of parasitic copepods on the body condition of the host fish in this environment, which is heavily degraded by human activities. In such a setting, the balance between host and parasite systems is disrupted, leading to a decline in fish production through direct mortality, reduced growth, fecundity, and stamina, as well as increased susceptibility to disease and predation, as noted by Euzet and Pariselle (1996).

CONCLUSION

The present study which focused on the diversity of gill parasitic copepods and the influence of various parameters on tilapia infestation, allowed to identify three copepod species: *Lamproglena monodi*, *Lernaea barnimiana* and *Ergasilus latus*. The relatively high parasitic diversity reflects a fairly well-structured population of these species. Furthermore, the study indicated that fish from the Ahondo station were the most heavily infested and showed poor body condition, likely due to the impact of these pathogens. The rainy season corresponded to the highest infestation rates. It also showed that male fish were more parasitized than females. All of this information provides a valuable baseline to be considered in future management and development programs aimed at enhancing the productivity of this fish species in the region.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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