

PREVALENCE, MEAN INTENSITY AND ABUNDANCE OF ECTOPARASITES IN CAGE- CULTURED NILE TILAPIA IN GHANA

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ABSTRACT

This study examined the prevalence, mean intensity, and abundance of ectoparasites in cage-cultured Nile tilapia in Volta Lake, Asuogyaman District, Ghana. Data on the peak infestation periods were collected using structured questionnaires administered to 30 cage farms. Five farms were purposively selected for monthly parasitological examinations over six months (February to July 2023), with 30 fish sampled from each farm per month. Ectoparasites were identified morphologically using taxonomic keys, and infestation parameters were estimated. The survey responses revealed two peak infestation periods: a major peak from February to March, and a minor peak from November to January. The ectoparasites identified included *Trichodina*, *Ichthyophthirius*, *Dactylogyrus*, *Gyrodactylus*, *Cichlidogyrus*, *Diplostomum*, *Myxosporean*, and *Argulus*. Significant monthly variations were observed in both the prevalence ($p = 0.004$) and abundance ($p = 0.0495$), with the highest levels observed in March. The percent prevalence, mean intensity, and relative abundance ranged from 3.3% to 51.77%, 0.51 to 2.04 and 1.7 to 4.4%, respectively. *Trichodina* was the most prevalent, intensive, and abundant ectoparasite genus. This study recommends longer-term seasonality work to better understand infestation trends and the identification of ectoparasites at the species level using molecular tools. Also, farmers should increase monitoring and apply preventive measures before and during peak infestation periods (February-March and November-January).

Keywords: Fish parasites, infestation, fish farms, Volta Lake.

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INTRODUCTION

Capture fisheries and aquaculture contribute approximately 15% of global animal protein and 6% of total dietary protein (FAO, 2024). Nonetheless, capture fisheries worldwide have plateaued over the past four decades, threatening the sustainability of fish availability (FAO, 2018). The alarming food and nutrition insecurity, along with the challenge of providing sufficient sustenance for 8 billion people by 2030, is becoming increasingly apparent amid the current population growth trend (Worldometer, 2020). Aquaculture has been recognized as a reliable source of first-class, high-quality fish protein, with its production and consumption cutting across diverse ecological, socioeconomic, cultural, and religious boundaries (Boyd *et al.*, 2022). A recent report by the FAO (2024) indicated that aquaculture production worldwide reached an all-time high at approximately 130.9 million tonnes in 2022, representing 51% of total aquatic animal production, surpassing capture fisheries for the first time. The first-sale value of aquaculture production was estimated to about USD 313 billion in 2022, reflecting its increasing economic importance within global aquatic food systems. Thus, aquaculture and related value chain activities have become essential systems for animal protein production because of their implications for food and nutrition security, as well as livelihoods and economic support, especially in African countries. Nevertheless, the industry's sustainability is at risk due to disease incidence (Subasinghe, 2005; Chan *et al.*, 2019).

Fish disease outbreaks are a major challenge in the aquaculture industry. In a report by Jensen (2023), fish pathogens and diseases were responsible for a total fish loss of USD 6 billion worldwide through mortality, reduced marketability, and cost of treatment, directing global attention to fish health issues in aquaculture (FAO, 2020; Ellis & Kiessling,

2016). Outbreaks of established and emerging diseases threaten the survival of aquaculture, with infectious diseases continually hindering the industry's growth. Diseases can reduce reproductive performance and negatively affect feed conversion efficiency, leading to reduced growth and overall performance of cultured fish (Tavares-Dais & Martins 2017).

In Ghana, aquaculture has grown tremendously into a viable economic activity, with governmental, international, and private efforts now playing pivotal roles from its early days to its current status (Ragasa *et al.*, 2022). The species cultured in the country are African catfish (*Clarias gariepinus*), African bony tongue (*Heterotis niloticus*) and Nile tilapia (*Oreochromis niloticus*) (Amenyogbe *et al.*, 2018). Nile tilapia accounts for 80% of the total aquaculture production in Ghana (MOFAD, 2020), and remains the most important farmed fish. Although significant growth in aquaculture production has been reported in Ghana in the past decade (MOFAD, 2010, 2020), recent outbreaks of fish diseases have reduced farmers' efforts to further increase production due to mass mortalities of fish, reduced yield and product quality, and low profitability (Amenyogbe *et al.*, 2018). Disease-causing organisms affecting the Nile tilapia industry in Ghana include bacteria, fungi, viruses, and parasites (Amenyogbe *et al.* 2018).

Although viral and bacterial diseases have attracted attention, there has been minimal focus on parasites. Parasites are ubiquitous, occurring in most ecosystems and infecting a wide range of hosts. They often persist in a dynamic equilibrium with their hosts, allowing survival and transmission without immediately harming them. (Iwanowicz, 2011). Changes in the environment alter the parasite–host equilibrium and cause disease or mortality in fish.

Parasite-induced mortality is frequently correlated with alterations in parasite abundance, community structure, and infestation rate. Fish with low parasite loads typically exhibit minimal symptoms, whereas heavily parasitized individuals may experience physiological impairments and, in severe cases, mortality. (Kotob *et al.*, 2016). Furthermore, parasites can cause mechanical damage (fusion of gill lamellae and tissue replacement), physiological damage (cell proliferation, immunomodulation, detrimental behavioral responses, and altered growth), and reproductive damage in fish (Marcogliese, 2005; Iwanowicz, 2011). Their initial infestation could also expose fish to secondary bacterial and viral infections (Nofyan *et al.*, 2015). The intensification of aquaculture in Ghana through increased tilapia production in many small- to large-scale cages in Volta Lake has raised concerns regarding the general health of the aquatic environment and the concomitant outbreak of diseases. Nile tilapia is the dominant fish cultured in cages on Volta Lake in Ghana (Karikari *et al.*, 2016) and contributes to approximately 80% of the country's aquaculture production (MOFAD, 2020, 2023), making tilapia cage culture an important subsector in the aquaculture industry in Ghana.

In view of the importance of tilapia cage culture, the recent outbreak of diseases in cage farms in Volta Lake has been of concern to both governmental and private stakeholders within the industry. Several efforts have been made to identify disease-causing agents as a primary step toward overcoming this challenge. For instance, Jansen *et al.* (2018) reported that fish pathogens such as *Streptococcus agalatae*, *S. iniae*, *Aeromonas hydrophila*, and *A. veronii* are responsible for mass fish mortality in cage farms.

In addition, the Infectious Spleen and Kidney Necrosis Virus (ISKNV) has been documented to cause mass fish mortality, especially at the fry and fingerling stages of tilapia (Ramirez-Paredes *et al.*, 2021). Although many studies have been conducted on bacterial infections in the country, minimal information exists on parasitic infestations, especially in fish cultured in cage farms in lakes. Nofyan *et al.* (2015) reported that ectoparasites may be responsible for secondary infections that precede viral and bacterial diseases. Osuigwe *et al.* (2011) noted that ectoparasites are closely associated with fish and pose various health challenges. They serve as vectors that transport potential pathogens under certain circumstances, such as high stocking densities, poor environmental conditions, and pollution (George, 2002; Edward & Ugwumba, 2010; Kolia *et al.*, 2021), and can consequently cause profound pathological changes that reduce the growth rate, quality, and survival of the fish, which could result in huge economic losses (Bichi & Dawaki, 2010).

Although appreciable information is available on the infestation of tilapia by parasites in earthen ponds and concrete tank culture systems in Ghana, there is a lack of knowledge regarding tilapia cultured in cages, and the available information is scanty and outdated (Amoako, 2006; Baidoo *et al.*, 2015). This study was inspired by parasitic infestations of Nile tilapia cultured in cages in Volta Lake. The scientific information generated from this study will contribute to the development of a comprehensive fish health management plan to control and manage fish diseases in the country. This study aimed to assess the prevalence, intensity, and abundance of ectoparasites in Nile tilapia cultured in cages in the Asuogyaman District of the Eastern Region of Ghana.

MATERIALS AND METHODS (METHODOLOGY)

Determination of Period of Occurrence of Ectoparasites

A structured questionnaire with both closed- and open-ended questions was administered to 30 Nile tilapia cage farms in Asuogyaman District to obtain information on the

occurrence and peak period of ectoparasites in the farms. The questionnaire was administered through face-to-face interviews, using a purposive sampling technique. The Kobo toolbox, an open-source platform for the collection, management, and visualization of data, was used in questionnaire administration. Table 1 show some questions that were asked and their response options.

Table 1. Some important questionnaire questions administered to farmers

Variable	Questions	Response options
Fish Mortality	Do you mostly experience mortalities?	Yes/ No
	When do you mostly experience mortalities?	February – April May – July August – October November – January
	How many fish/cage/day do you record?	
	Frequency of dead fish removal	Never Daily/several times per day Every 2 to 3 days Weekly Monthly Occasional
Parasitic Infestation	Do you see signs of parasitic infestation?	Yes/ No
	What are the signs you see?	Dark skin Rapid movement of operculum Aggression of fish on water surface Gulping for atmospheric Oxygen Lesions or abrasions on the skin Erratic swimming of fish Eye ball(s) missing from the socket
	In which of these months do you see such signs?	February – April May – July August – October November – January

Farm Selection and Fish Sampling for Parasite Identification

Based on the responses to the questionnaire, the period for collecting fish samples for ectoparasite identification was scheduled to coincide with the time of peak parasite infestation. Five farms (Figure 1) were selected (based on the willingness of farmers to engage in the study with three farmers upstream and two farmers downstream) for fish sampling for monthly parasitological examination over a

6-month period (February to July). Thirty (30) fish samples were randomly collected (using a scoop net) from production cages at each of the selected farms for a total of 900 fish samples. Fish were sampled from production cages available at the time of sampling. The fish were then transported live in oxygen-free bags to the laboratory at the Aquaculture Research and Development Center (ARDEC) in Akosombo for examination.

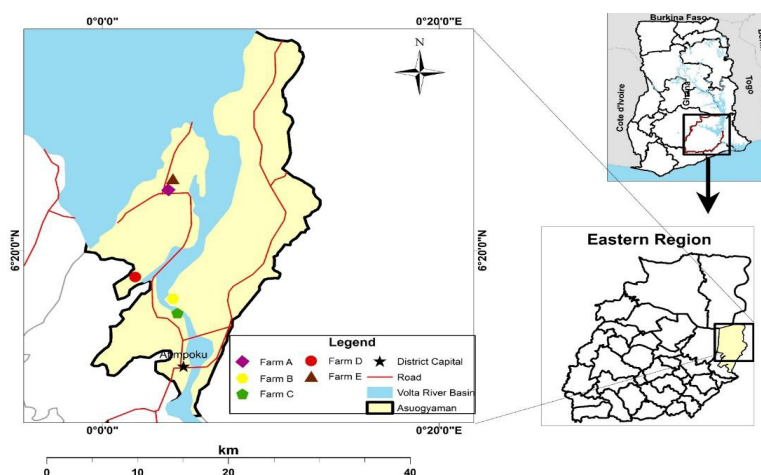


Figure 1. A map of Ghana showing the location of cage fish farms where fish samples were collected.

Parasitological Examination of Samples

Physical examination of the fish was performed with the naked eye and a magnifying glass with magnification of 10x, and macroparasites observed on the body or skin of the fish were counted and recorded. Subsequently, mucus was carefully scraped from the skin, smeared on clean glass slides, and covered with coverslips. In addition, a section of the first gill arch on both sides of the fish was severed with dissecting scissors and spread thinly on a glass slide. Distilled water was added to each specimen to prevent drying. This procedure was repeated for all the fish samples. All the specimens were examined

under a 400x magnification lens using a light microscope (Leica DM 500). Ectoparasites were identified morphologically using taxonomic keys developed by Pouder *et al.* (2005) and Untergasser (1989).

Determination of Prevalence, Mean Intensity and Abundance of Ectoparasites

The prevalence, intensity, and abundance of the identified ectoparasites were estimated using the mathematical formula of Bush *et al.* (1997) as follows:

$$\text{Prevalence} = \frac{\text{number of fish infested with a particular parasite species}}{\text{total number of hosts examined}} \times 100\%$$

$$\text{Mean intensity} = \frac{\text{total number of parasites} \in \text{host fish}}{\text{total number of infested hosts}}$$

$$\text{Abundance} = \frac{\text{number of parasites counted}}{\text{total number of fish examined}}$$

Data Analysis

Descriptive analysis was performed within the Kobo toolbox where responses were automatically processed to generate frequencies, percentages, and graphical summaries which were used in data interpretation and presentation.

One-way Analysis of Variance was used to determine significant differences in the prevalence, mean intensity, and abundance of ectoparasitic infestations between the months of sampling. Tukey's Multiple Comparison post hoc test was used to compare all possible pairs of means. The p-value was considered significant at $\alpha=0.05$. GraphPad Prism 5

software was used to perform the analyses and generate all graphs.

RESULTS AND DISCUSSION

Peak Period of Occurrence from Questionnaire Responses

Farmers observed the presence of ectoparasites on Nile tilapia in their cages year-round (Figure 2), with a higher occurrence during specific months. The major and minor peak periods of occurrence were found to range from February to April (53.6%) and November to January (42.9%), respectively. The shortest period of occurrence was between August and October (10.7%).

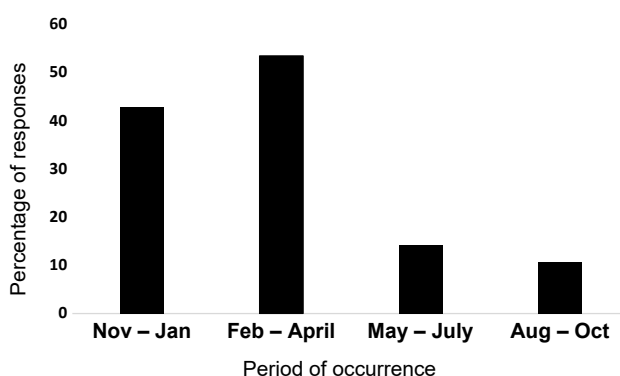


Figure 2. Response of fish farmers during the period of occurrence of ectoparasites in Nile tilapia cage farms in Volta Lake.

Ectoparasites Identified with Their Prevalence, Mean Intensity and Abundance

Eight different genera of ectoparasites and two unidentified ectoparasites were identified during this study (Table I). Ectoparasites from the following genera were recovered: parasitic ciliates *Trichodina* and *Ichthyophthirius*, monogeneans *Dactylogyrus*, *Gyrodactylus*, *Cichlidogyrus*, *Diplostomum* and Crustacean branchiura *Argulus*. In addition, *Myxosporeans*

and two unidentified organisms were identified. These parasites showed affinity for the skin or gills of the fish (Table II). The skin recorded the most dominant parasite occurrence, with a percentage of 68.20%. The most prevalent parasite, *Trichodina* (65.70%), showed a higher affinity to the skin than to the gills, whereas the least prevalent, *Ichthyophthirius* (0.16%), infested only the skin.

Table II. Total number of ectoparasites recovered from the gills and skin of cage-cultured Nile tilapia from farms on the Volta Lake. Asterisks represent ectoparasites that could not be identified.

Parasite	February		March		April		May		June		July		Total
Genera	Gills	Skin	Gills	Skin	Gills	Skin	Gills	Skin	Gills	Skin	Gills	Skin	
<i>Trichodina</i>	52	310	145	904	20	72	29	1035	176	312	10	270	3335
<i>Dactylogyrus</i>	105	12	209	6	47	2	62	1	81	0	54	0	579
<i>Gyrodactylus</i>	5	14	5	33	17	2	0	31	2	6	1	7	123
<i>Myxosporean</i>	0	55	0	73	0	0	0	10	0	0	0	163	301
<i>Argulus</i>	0	5	0	8	0	7	0	12	0	0	0	5	37
<i>Cichlidogyrus</i>	99	0	175	1	94	2	32	0	20	0	43	0	466
<i>Diplostomum</i>	0	0	0	0	0	0	0	0	0	0	0	137	137
<i>Ichthyophthirius</i>	0	0	0	0	0	0	0	0	0	8	0	0	8
*Unidentified 1	0	0	0	0	0	0	12	0	0	0	0	0	12
*Unidentified 2	32	11	0	0	0	0	17	8	0	0	0	0	68

Table III. Total number of individual parasites recovered from the gills and skin of cage-cultured Nile tilapia as indicator of organ preference.

Ectoparasites	Infested organ	
	Gills	Skin
Trichodina	432	2903
Dactylogyrus	558	21
Gyrodactylus	30	93
Myxosporean	0	301
Argulus	0	37
Cichlidogyrus	463	3
Diplostomum	0	137
Ichthyophthirius	0	8
*Unidentified 1	12	0
*Unidentified 2	49	19
TOTAL	1544	3512

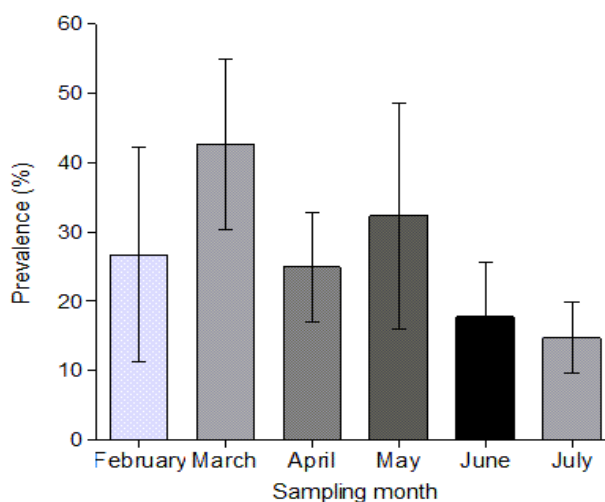


Figure 3. Mean monthly percent prevalence of ectoparasites from the five Nile tilapia cage farms on Volta Lake. Error bars represent mean±standard deviation.

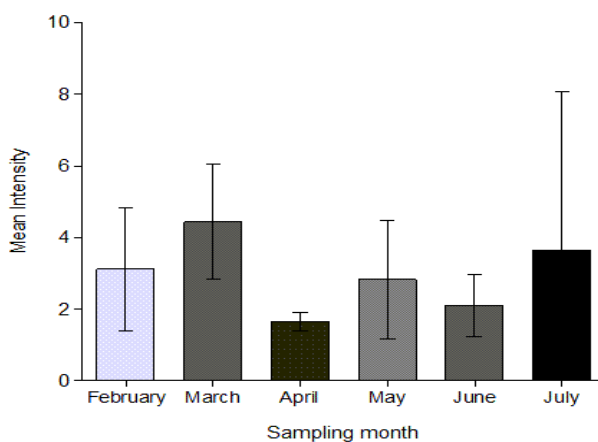


Figure 4. Mean intensity of ectoparasites of cage-cultured Nile tilapia from five farms on the Volta Lake. Error bars represent mean $\pm$ standard deviation.

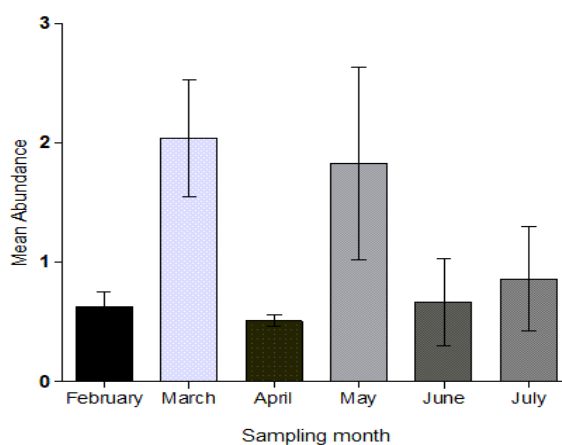


Figure 5. Mean abundance of ectoparasites of cage-cultured Nile tilapia from five farms on the Volta Lake. Error bars represent mean $\pm$ standard deviation.

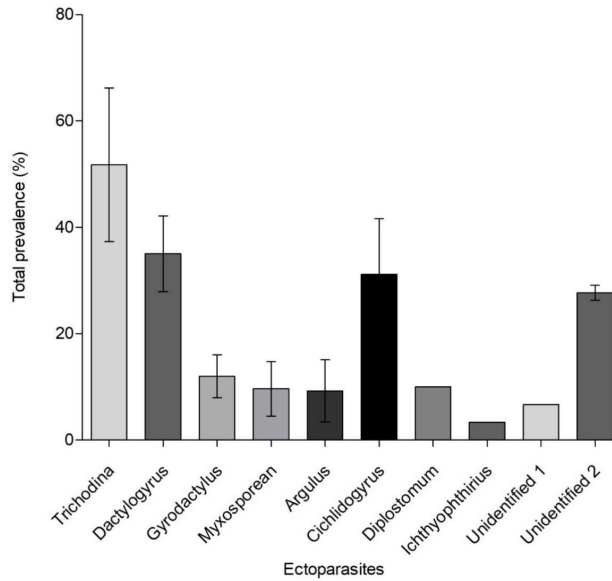


Figure 6. Mean percentage prevalence of ectoparasites encountered during the study period. Error bars are mean $\pm$ standard deviation.

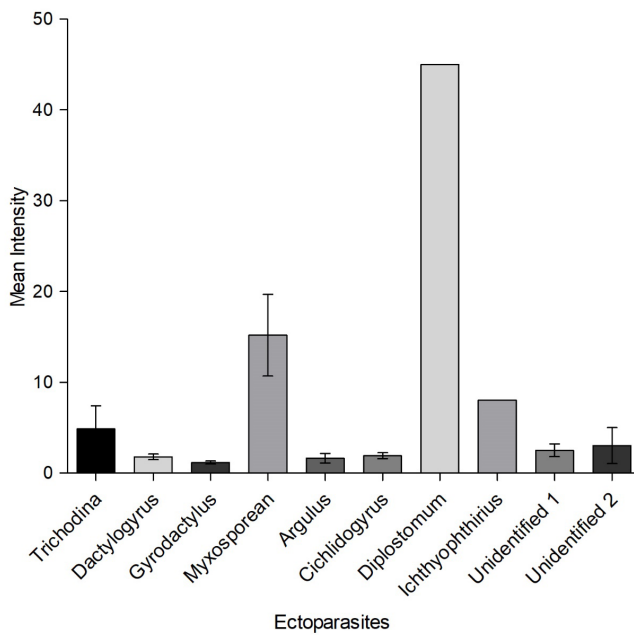


Figure 7. Mean intensity of ectoparasites encountered during the study period. Error bars are mean $\pm$ standard deviation.

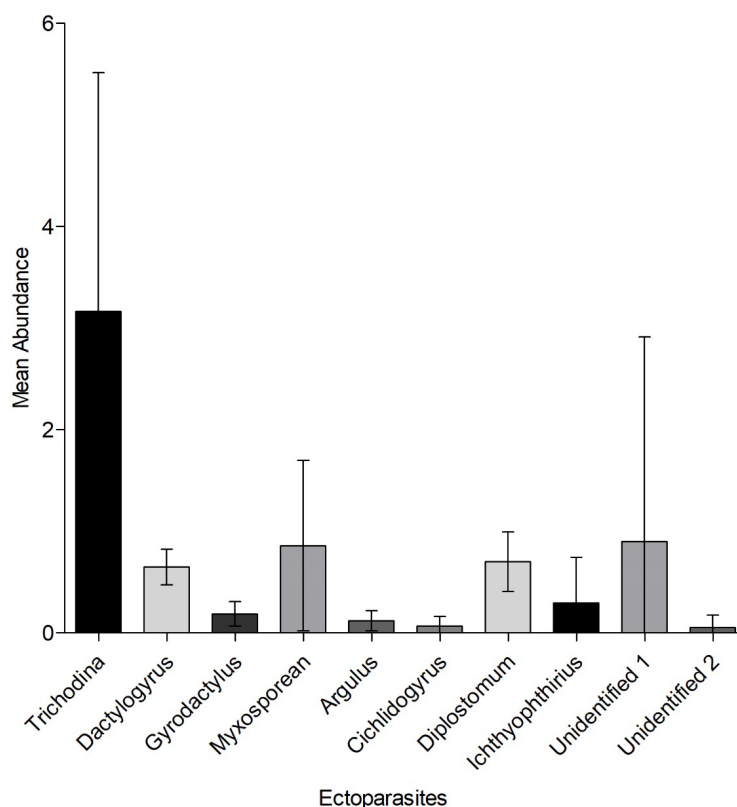


Figure 8. Mean abundance of ectoparasites encountered during the study period. Error bars represent mean $\pm$ standard deviation.

Figures 3, 4, and 5 represent the monthly prevalence, mean intensity, and abundance of ectoparasitic infestation of cage-cultured *O. niloticus*. The prevalence ranged widely, from 42.58% in March to 14.72% in July. The prevalence rates in February, April, May, and June were 26.7%, 24.88%, 32.34%, and 17.73%, respectively (Figure 4). There was a significant difference ($p = 0.0040$) in prevalence of ectoparasites in the months, and the differences were between March and June/July from the Tukey test.

The mean intensities of the ectoparasites per month were 3.1, 4.4, 1.7, 2.8, 2.1 and 3.6 from February to July, respectively (Figure 5). March had the highest mean intensity, whereas the

lowest was observed in April. There was no significant difference in the monthly mean intensities ($p = 0.3394$).

The abundance of ectoparasites was the highest in March (2.04) and lowest in April (0.51). The mean abundance of ectoparasites was approximately 2- to 3-fold lower in February, June, and July than in March. The mean ectoparasite abundance was only 10.29% lower in May than in March (Figure 6).

There was a significant difference in the abundance of ectoparasites between the months ($p = 0.0495$).

Specifically, the prevalence of ectoparasites was in the following order: *Trichodina* > *Dactylogyrus* > *Cichlidogyrus* > Unidentified 2 > *Gyrodactylus* > *Diplostomum* > *Myxosporean* > *Argulus* > Unidentified 1 > *Ichthyophthirius* (Figure 6).

Figure 7 shows that *Diplostomum* recorded the highest mean intensity (45), and *Gyrodactylus* recorded the lowest was *Gyrodactylus* (1.15). After *Diplostomum*, *Myxosporean* had the highest mean intensity, followed by *Ichthyophthirius*, *Trichodina*, Unidentified 2, unidentified 1, *Cichlidogyrus*, *Dactylogyrus* and *Argulus*.

The abundance of various ectoparasitic infestations, as presented in Figure 8, shows that *Trichodina* was the most abundant ectoparasite, followed by the unidentified 1, *Myxosporean*, *Diplostomum*, *Dactylogyrus*, *Ichthyophthirius*, *Gyrodactylus*, *Argulus* and *Cichlidogyrus*. The least abundant genera was unidentified at 2.

DISCUSSION

Based on the survey results, two main peak periods of ectoparasite occurrence were identified and categorized as major and minor periods. The major peak period of ectoparasite occurrence ranged from February to April, and the minor peak period of occurrence ranged from November to January. These periods are both within the dry climatic season in Ghana, although they vary within areas or parts of the country. In northern Ghana, the dry season is from November to May, whereas the wet season is from May to October (Environmental Protection Agency, 2011). Concurrently, the dry season in the southern region spans from November to March and is marked by minimal to no rainfall. The primary rainy season (March to July) and secondary rainy period (September to November) occur solely within the southern sector of the country (Padi, 2017; Ghanaweb.com, 2023), which is the specific location of

the study. Correspondingly, the period when respondents noted the highest occurrence of ectoparasites in the survey aligned with the dry climatic season in southern Ghana.

This study recorded some ectoparasites present in cage farms in the Asuogyaman District in the Eastern Region of Ghana. Eight ectoparasites belonging to five parasitic groups were identified. These are Protozoan ciliates (*Trichodina* and *Ichthyophthirius*), Monogenean (*Dactylogyrus*, *Gyrodactylus* and *Cichlidogyrus*), Digenean (*Diplostomum*), Crustacean Branchiura (*Argulus*), and Myxozoan (*Myxosporean*). The highest number of parasites recorded was *Trichodina* and the lowest was *Ichthyophthirius* (Table 1). Parasites maintain a dynamic balance with their hosts, but alterations in the environment can disrupt this balance, potentially leading to disease outbreaks (Kotob *et al.*, 2016). Increased stocking densities, combined with environmental fluctuations or stress factors, can create conditions that promote rapid reproduction and spread of parasites. However, high stocking densities, coupled with fluctuations in environmental conditions and/or stress, can favor parasite proliferation (Shinn *et al.*, 2023).

Moreover, transfer or sharing of equipment can lead to the introduction of ectoparasites on farms (Ali *et al.*, 2020). Equipment such as nets can harbor parasites that can be introduced into another farm when shared (Ali *et al.*, 2020). The survey showed that approximately 68% of the respondents shared equipment with at least one farm. Regarding the ectoparasite composition found in cage farms within Volta Lake, Alhassan *et al.* (2018) identified *Trichodina* spp., *Ichthyophthirius* multifiliis, *Dactylogyrus* spp., *Argulus* spp., *Lernaea* spp. and *Diplostomum* spp.

Baidoo *et al.* (2015) discovered two protozoans, *Trichodina* spp. and *Ichthyophthirius* multifiliis, along with monogeneans, during their investigation of parasites in concrete ponds in Ghana. Additionally, Amoako (2006) documented two protozoans, *Trichodina* spp. and *Tetrahymena* sp., along with monogeneans in *O. niloticus* within aquaculture production systems in the Ashanti Region of Ghana. These parasites were isolated from the gills and skin of the host. Notably, certain parasites display a preference for adhering to external surfaces, targeting particular parts of the host, and often dominate specific growth phases (Indahsari *et al.*, 2019; Anshary *et al.*, 2022). For example, *Argulus* is reported to have a preference for the skin of fish and not for any other organ of fish (Klinger and Floyd, 2013; Steckler and Yanong, 2013). *Diplostomum* spp. mostly infests the eyes of fish. Fish develop impaired vision that is associated with clinical signs such as cataract formation, exophthalmia, lens dislocation, and eventually blindness (Shinn *et al.*, 2023). The affinity of some ectoparasites to specific organs underscores the results obtained in this study, where *Argulus* spp., *Ichthyophthirius* spp., *Diplostomum* sp., and *Myxosporean* were recovered only from the skin. Some studies have also demonstrated the recovery of specific ectoparasites from multiple organs (Yusni and Rambe, 2019; Alhassan, 2018).

In the present study, *Dactylogyrus* spp., *Trichodina* spp., and *Gyrodactylus* spp. and *Cichlidogyrus* spp. were found on both the skin and gills. All sampling months exhibited a high prevalence, mean intensity, and abundance of ectoparasites compared to those reported by Amoako *et al.* (2006), Baidoo *et al.* (2015), and Alhassan *et al.* (2018). The highest ectoparasitic prevalence, mean ectoparasitic intensity, and ectoparasitic abundance were observed in March. According to the respondents, ectoparasites occurred year-round (Figure 3), with a peak period occurring between

February and April. This period coincides with the dry climatic season, especially in the southern parts of the country (Environmental Protection Agency, 2011), where this study was conducted. During these periods, the evaporation rate increases, and rainfall is drastically reduced to zero (Padi, 2017). This leads to low water volumes in open waters, resulting in relatively high nutrient loads, which supports the thriving and proliferation of fish ectoparasites (Smallbone *et al.*, 2016), accounting for the high prevalence, mean intensity, and abundance of ectoparasites in this study.

In addition, *Trichodina* was the most prevalent (52%) and abundant (3.3) ectoparasite among all the ectoparasites identified, confirming the reports by Enyidi and Uwanna (2019), Jerônimo *et al.* (2020), and Akoll *et al.* (2012) that *Trichodina* species are major freshwater ectoparasites mostly found on the skin and gills of cultured *O. niloticus*. Anshary *et al.* (2022) highlighted that *Trichodina* can exist in various life forms within different aquatic environments, functioning as epibionts, symbionts, free-living entities, or parasites, and affecting a wide array of aquatic vertebrates and invertebrates. The notably high prevalence and abundance of *Trichodina* can be attributed to its reproductive method. *Trichodina* reproduces via binary fission and employs direct transmission, allowing rapid proliferation, particularly in fish populations subjected to poor environmental conditions. Enyidi and Uwanna (2019) documented the abundance of *Trichodina* at 11.1 in Nile tilapia residing in earthen ponds in Nigeria. However, the mean intensity of *Trichodina* was lower.

Generally, *Trichodina* tends to occur in healthy fish at low intensities, often with a minimal impact on their well-being. (Anshary *et al.*, 2022).

However, the high abundance of *Trichodina* parasites causes irritation to the skin of Nile tilapia owing to their movement activity and mechanical lesions of the parasite, causing pathological changes in the infected organs (Maciel *et al.*, 2018). They attach to the surface of the epithelial layer of the host so that the sharp blade of denticle rings causes harm and irritation to the fish epithelium, especially when actively moving while searching for food (Maciel *et al.*, 2018). This compromises the immune system of the fish and reduces the protective barrier (mucus) provided by the skin. Therefore, fish that have been infected with *Trichodina* may have increased susceptibility to other viral and bacterial infections. The presence of *Trichodina* species plays a critical role in the success of aquaculture, many of which have been reported to cause disease outbreaks in aquaculture facilities, leading to economic losses, especially in intensive production systems such as cage culture (Shinn *et al.*, 2015; Anshary *et al.*, 2022; Shinn *et al.*, 2023).

In general, fish parasitic diseases can be influenced by an imbalance in the interaction between fish and parasite factors and aquatic environment (culture) conditions. Nonetheless, the occurrence and magnitude of parasitic diseases are closely related to the sanitary conditions in water (Hossain *et al.*, 2007). It has been postulated that water pollution influences the pathogenicity potential of ectoparasites (Ojwala *et al.*, 2018) and increases disease susceptibility (Biswas & Pramanik 2016) by lowering the defense and immunogenic status of fish (Noor El-Deen *et al.*, 2015). Environmental factors, such as water temperature, dissolved oxygen, salinity, hydrogen ion concentration, and eutrophication, have been reported to have a positive influence on the occurrence of parasitic populations and communities (Lagrue *et al.*, 2011; Zargar *et al.*, 2012; Ojwala *et al.*, 2018). Stress is related to lower water quality (lower values of dissolved oxygen, inadequate

values of temperature and pH, and high levels of organic matter in the water), which provides a good environment for the proliferation of protozoan parasites and the occurrence of pathogenic agents, especially for body surface parasites such as *Trichodina* and *Ichthyophthirius* (Wanja *et al.*, 2020). Parasites are recognized as an important limiting factor in the development of intensive aquaculture, resulting in massive mortalities and reduced growth rates (Iwanowicz, 2011). This could have resulted in the high prevalence and abundance of some ectoparasites, especially *Trichodina* and monogeneans, in this study. For example, *Cichlidogyrus* parasites in the gills damage the gills of fish and make them pale. They do this by clinging to the gills of fish and sucking the blood through the gills and absorbing nutrients from the host, eventually causing the death of fish (Borzák *et al.*, 2021; Székely *et al.*, 2021).

CONCLUSION

Ectoparasites are present in Nile tilapia cultured in cage farms in Volta Lake in the Asuogyaman District of the Eastern Region of Ghana, with major and minor peak periods spanning February to April and November to January, respectively, coinciding with the dry season in Ghana. The ectoparasite genera identified were *Trichodina*, *Ichthyophthirius*, *Dactylogyrus*, *Gyrodactylus*, *Cichlidogyrus*, *Diplostomum*, *Myxosporean* and *Argulus*. *Trichodina* recorded the highest prevalence, intensity, and abundance in cage-cultured Nile tilapia in the lake, whereas March emerged as the month with the highest prevalence, mean intensity, and abundance of ectoparasites, which coincides with the results of the survey. This study recommends longer-term seasonality research to better understand infestation trends and the identification of ectoparasites at the species level using molecular tools.

Farmers should increase monitoring and apply preventive measures before and during peak infestation periods (February–March and November–January).

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DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest.

AUTHOR CONTRIBUTIONS

AA contributed to field data collection, laboratory analysis, data analysis, writing of the manuscript, AS conceptualized the idea and supervised the project, sourcing of funds, design and implementation of the research, review of manuscript, and DCP contributed to conceptualization, design and implementation of research, analysis of the results, and to the writing of the manuscript.

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