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Seasonal comparison of gastrointestinal parasites in captive birds at FUNAAB Zoological Garden, Ogun state, Nigeria

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ABSTRACT

Captive wild birds in zoological gardens play vital roles in the conservation and educational purposes but are highly vulnerable to gastrointestinal parasitism, which threatens their survival and welfare. This study investigated seasonal and interspecies variation in gastrointestinal parasites among six bird species housed at the Federal University of Agriculture, Abeokuta Zoological Garden, Nigeria. 46 fresh fecal samples were collected during rainy (August–September 2023) and dry (January–February 2024) seasons and analyzed using flotation technique, formol-ether concentration technique and McMaster egg count techniques. The results revealed marked seasonal differences in parasite prevalence and intensity, with higher burdens generally recorded during the rainy season. Common parasites included Ascaris spp, Entamoeba spp, Giardia spp, Strongyloides spp, and Ancyclostoma spp, with ostriches, geese, and mallard ducks showing the heaviest infections, particularly those with ground contact, as reflected by higher egg per gram (EPG) counts. Notably, Ascaris spp. infection intensity was highest in ostriches (40.75 ± 1.55 and 61.00 ± 1.41 EPG) and geese (33.75 ± 11.39 and 25.00 ± 2.87 EPG) during the rainy and dry seasons, respectively. Statistical analysis confirmed significant seasonal variation in key parasites, highlighting the influence of environmental conditions on transmission dynamics. These findings underscore the importance of seasonally informed parasite monitoring, targeted treatment schedules, and improved enclosure hygiene in zoological settings. Strengthening parasite control not only enhances avian welfare but also contributes to broader conservation outcomes in tropical zoos.

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Introduction

Captive wild birds are invaluable components of zoological gardens, playing significant roles in biodiversity conservation, public education, and ecotourism. However, these species are increasingly vulnerable to infectious diseases particularly gastrointestinal parasitism which threatens their health, reproductive success, and survival (Atkinson et al., 2008). Gastrointestinal parasites (GIPs), including nematodes, cestodes, trematodes, and protozoans, are frequently observed in avian collections and often cause subclinical or clinical disease that may culminate in mortality if left unmanaged (Fowler and Miller, 2020). These parasites affect nutrient uptake, immune function, and gut physiology, and are known to impair growth rates, egg production, and host behavior (Clayton and Moore, 2017; Hudson et al., 2006).

In captivity, conditions such as restricted space, fecal accumulation, and close contact between birds enhance the transmission of infective stages (eggs, oocysts, and larvae) through contaminated feed, water, and soil (Papini et al., 2012; Citino, 2003). Moreover, poor hygiene and inadequate deworming schedules often increase parasite burdens, particularly in species such as ostriches (Struthio camelus), mallard ducks (Anas platyrhynchos), and peacocks (Pavocristatus) that have close ground contact. Common helminths such as Ascaridia galli, Heterakisgallinarum, and Raillietina spp., and protozoa like Eimeria spp. and Giardia spp. have been

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repeatedly identified in zoo birds worldwide (Borji et al., 2012; Ogbaje et al., 2012).

Environmental conditions—particularly climatic variables like temperature, rainfall, and humidity—are critical in shaping the survival and transmission of these parasites (Dubey, 2014; Gillespie and Chapman, 2008). In tropical countries like Nigeria, the distinction between the rainy season (characterized by high humidity and moisture retention) and the dry season (marked by lower humidity, reduced vegetation, and heat stress) creates dynamic shifts in parasite ecology. Moist conditions during the rainy season favor the development and persistence of infective stages, especially for soil-transmitted helminths and waterborne protozoans (Atkinson et al., 2008; Taylor et al., 2016). Conversely, while dry conditions may suppress the external survival of these organisms, they may simultaneously weaken host resistance due to dehydration, poor nutrition, and oxidative stress (Gillespie and Chapman, 2008; Gomez and Nichols, 2013).

Despite this known interplay between parasite biology and environmental conditions, many parasitological studies have taken a cross-sectional rather than longitudinal approach—often assessing parasite burden at a single point in time without accounting for seasonal variation. For example, Borji et al. (2012) documented parasitic infections in ornamental birds in Iran, while Ebrahim et al. (2012) found a 34.8% infection rate in avian species across West Iranian aviaries. However, neither study explored fluctuations in prevalence across climatic seasons. In Nigeria, Ogbaje et al. (2012) reported high helminth loads in chickens slaughtered in Makurdi but did not stratify findings by weather period. Similarly, studies like Otegbade and Morenikeji (2014) confirmed helminths in captive birds in southwest Nigeria, yet lacked seasonal context. Egbetade et al. (2014) conducted a survey on helminth parasites in zoo birds and observed widespread infections across species, yet their work similarly did not account for seasonal fluctuations or multi-species comparison within controlled zoo environments.

Additionally, few studies conduct comparative multi-species analysis in a single zoological setting, which is critical for understanding host-specific risk profiles. Different bird species exhibit varying behaviors, diets, immune responses, and environmental interactions that can influence susceptibility to parasitism (Fowler & Miller, 2020; Gillespie, 2006). For instance, ground-dwelling species like ostriches and ducks are more likely to come into contact with contaminated substrates than arboreal birds like grey parrots (Psittacus erithacus). Seasonally stratified research is essential for informing targeted treatment and preventive care in captive bird populations. Without understanding how parasite prevalence fluctuates over time, zoo veterinarians' risk either under-medicating or overusing anthelmintic, which may lead to ineffective parasite control and the emergence of drug-resistant strains (Taylor et al., 2016). Furthermore, neglecting seasonal variation may mask the true extent of infection and misinform conservation planning, especially for endangered or long-lived species like cranes and parrots, whose reproductive cycles can be severely affected by chronic parasitism.

To address these critical gaps, this study investigates the seasonal and interspecies dynamics of gastrointestinal parasites among six captive wild bird species—ostrich (Struthio camelus), geese (Anser spp.), African crowned crane (Balearica regulorum), grey parrot (Psittacus erithacus), peacock (Pavo cristatus), and mallard duck (Anas platyrhynchos)—housed at the Federal University of Agriculture, Abeokuta (FUNAAB) Zoological Garden in Ogun State, Nigeria. Fecal samples collected during both rainy and dry seasons were analyzed to:

(1) identify prevalent parasite species;

(2) compare infection intensity and prevalence between seasons and

(3) examine species-specific patterns of susceptibility.

By situating the analysis in a tropical, managed zoo environment, this research provides a robust, comparative, and ecologically-informed model of avian parasitism that reflects both biological and environmental complexities. The findings will inform targeted parasite control strategies, improve animal welfare, and contribute to broader conservation efforts in captive wildlife populations, particularly in tropical zoological parks.

Materials and methods

Study area

The study was conducted at the Federal University of Agriculture, Abeokuta (FUNAAB) Zoological Garden, located in Abeokuta, Ogun State, Nigeria. FUNAAB Zoological garden is located at 7.22087°N, 3.44655°E, or 7°13'15.15"N, 3°26'47.59"E. The zoo houses a variety of captive wild and exotic bird species within enclosed and semi-natural habitats. Ogun State lies within the humid tropical rainforest zone of southwestern Nigeria and experiences two major seasons: the rainy season (April–October) and the dry season (November–March). The average annual rainfall ranges from 1,000 to 1,500 mm, while temperatures typically range between 24°C and 32°C. There are varieties of animal species in the zoological park; and is divided into 6 sections for proper management. These sections include; Non-human primates, Carnivores, Ungulates, Rodents, Reptiles and birds. The bird samples collected in the park are classified in Table 1. Some animals are housed in uncemented enclosures, while others are housed in cemented enclosures and cages, which are

cleaned on a daily basis. Each species of the animals was kept separately in a large area which is structured in ways that mimic their natural environment and allows for free movement. The zoological park is demarcated and fenced to prevent movement by poachers and random individuals.

Ethical considerations

All procedures adhered to ethical guidelines for animal research. Sample collection involved non-invasive methods, and no birds were harmed or restrained during the process. All handling and laboratory procedures were carried out using protective equipment and in compliance with biosafety protocols to safeguard both animal welfare and researcher safety.

Table 1: Taxonomic classification of captive wild bird species in FUNAAB Zoological Park whose fecal samples were analyzed in the study

Common name	Scientific name	Family	Order
Ostrich	*Struthio camelus*	Struthionida	Struthionifo s
Geese	*Anser anser*	Anatidae	Anseriforme
African crowned Crane	*Balearica pavonina*	Gruidae	Gruiformes
Grey parro	*Psittacus erithacus*	Psittacidae	Psittaciform
Peacock	*Pavo cristat*	Phasianidae	Galliformes
Mallard du	*Anas platyrhynch*	Anatidae	Anseriforme

Study design and duration

This research adopted a longitudinal, observational study design, with fecal sample collections occurring across two climatic periods:

- Rainy season: August–September 2023
- Dry season: January–February 2024

This design was chosen to enable comparative evaluation of parasite prevalence and burden between the two seasons.

Pre-survey investigation

A pre-survey investigation was carried out in the zoological garden in order to document the number of captive bird species present in the garden, their sex, the environment of the animals and how readily available their stool specimen. Information about the constituents of their diet was also recorded.

Sample collection

Early morning and freshly voided fecal samples of birds were collected before routine cleaning of all cages in the zoo. Samples were collected weekly for 4 weeks. All samples were picked from the ground by utilizing a sterile scoop for each animal species to avoid cross contamination. Each sample was kept in a properly labeled sterile bottle i. e. name of bird. Immediately after collection, fecal samples were preserved with sodium-acetate acetic acid formalin solution (SAF) before being taken to the laboratory for analysis. All samples were examined within 48 hours of collection.

Laboratory analysis

Fecal samples were subjected to both qualitative and quantitative parasitological techniques following standard protocols:

Direct wet mount method

A small quantity of feces was emulsified with normal saline on a clean glass slide, covered with a coverslip, and examined under the microscope (×10 and ×40) for motile protozoan trophozoites and helminth ova.

Formol-ether concentration technique

Approximately 1 g of feces was emulsified in 10% formalin and mixed with diethyl ether, then centrifuged at 3,000 rpm for 5 minutes. The sediment was examined microscopically to detect cysts, oocysts, and ova, especially in low-intensity infections.

1g of stool sample was emulsified in 7 ml of 10% formalin to preserve parasite morphology. The suspension through a sieve was passed into a centrifuge tube. This was done to remove large particles and undigested food from the stool sample. 3 ml of ethyl acetate was added and the tube was stoppered tightly and shaken vigorously for 30 seconds to mix. The tube was then centrifuged at 2000 rpm for 2 minutes. After centrifugation, the stopper was removed and the supernatant (ether, debris, and formalin layers) poured off leaving only the sediment. The sediment was then re-suspended in a drop of formalin and placed on a glass slide with a coverslip. Slide was examined under 10x and 40x objectives for parasite stages (Suwansaksri et al. 2002).

Floatation method

Saturated sodium chloride solution was used as the floatation medium. The method was applied to detect lighter helminth eggs and coccidian oocysts, exploiting their buoyancy in the high-density solution. 2g of feces was mixed thoroughly with 10ml of saturated sodium chloride solution. The mixture was stirred until homogenized. The suspension was then passed through a cheesecloth into a clean beaker to remove large particles. The filtrate was poured into a test tube until nearly full. The test tube was carefully top up with flotation solution so a convex meniscus

forms at the rim. A coverslip was placed gently on the meniscus and left for 10–15 minutes to allow eggs/cysts to float and adhere to the coverslip. The coverslip was lifted vertically and placed on a glass slide. The slide was examined under 10x and 40x objectives for parasite eggs or cysts (Christie et al., 2011; Akande and Alohutade 2021).

Mcmaster egg counting technique

To estimate egg per gram (EPG) and oocyst per gram (OPG) counts, the McMaster method was employed for samples positive for helminth eggs or protozoan oocysts. This provided a quantitative measure of parasite burden, facilitating seasonal comparison.

2 g of feces was mixed with 28ml of saturated sodium chloride until the mixture was homogeneous. The mixture was filtrated through a cheesecloth to remove large debris and the filtrate was collected in a clean beaker. Using a pipette, both chambers of the McMaster slide were filled with the filtrate. Slide was made to stand for 5–10 minutes in order for the eggs to float to the grid surface. The slide was then examined under a 10x objective lens. All eggs within the grid areas of both chambers were counted Georgi (1980)

$$EPG = \frac{\text{Number of eggs counted X total volume (30ml)}}{\text{Volume of counted chamber (ml) X weight of feces in (g)}}$$

Identification:

Parasites were identified based on morphological characteristics using standard parasitology keys and guides (Soulsby, 1982). Photographs and measurements of identified parasites were taken for documentation.

Quantification: The number of parasite eggs, cysts, or larvae per gram of fecal material were recorded for each sample to assess the infection intensity.

Data Analysis

Data was entered and cleaned using Microsoft Excel and analyzed using SPSS version 25. Prevalence was expressed as the percentage of positive samples per species per season. Parasite burden (EPG/OPG/CPG) was analyzed using descriptive statistics and independent samples t-tests to compare seasonal means. Statistical significance was set at $p < 0.05$.

Chi-square tests were used to assess differences in parasite prevalence between seasons and species. Where appropriate, results were visualized using bar charts and line plots to highlight seasonal dynamics.

RESULTS

Comparative analysis of Gastrointestinal Parasites (GIPs) present in captive birds

The presence of GIPs in fecal samples from various wild bird species in the FUNAAB Zoological Garden is presented in Table 2. In the rainy season, Ascaris spp. was detected in Crowned Cranes, Mallard Ducks, and Ostriches. Giardia spp. was found in African Grey Parrots and Crowned Cranes, while Entamoeba spp. was identified in African Grey Parrots and Mallard Ducks. Strongyloides spp was notably present in Crowned Cranes, Mallard Ducks, and Ostriches, but absent in other species. No birds tested positive for Enterobius spp., Trichostrongylus spp., or Trichuris spp. during the rainy season.

In the dry season, the presence of parasites shifted slightly. Ostriches showed consistent infections with Ascaris spp., Entamoeba spp., and Strongyloides spp. in both seasons. Mallard Ducks retained infections with Ascaris spp. and Strongyloides spp., while African Grey Parrots again tested positive for Giardia spp. and Entamoeba spp. These variations suggest seasonal differences in exposure and transmission dynamics, potentially due to environmental and behavioral factors affecting parasite survival and host interaction.

Table 2: Presence of Parasites in Samples in Dry season

This table summarizes the presence of GIPs detected in fecal samples of bird during the dry season. Parasite presence is denoted by (+), absence by (−), with semi-quantitative grading of infection intensity indicated by (+), (++), or (+++) where applicable. The table compares parasite occurrence across both rainy and dry seasons for each species.

Animal	*Ascaris* spp (Dry/Rainy)	*Entamoeba* spp (D/R)	*Enterobius* spp (D/R)	*Giardia* spp (D/R)	*Ancyclostoma* spp (D/R)	*Strongyloides* spp (D/R)	*Trichostrongylus* spp (D/R)	*Trichuris spp* (D/R)
Ostrich	++ /+	+/+	–/–	–/–	–/+	+/–	–/–	–/–
Peacock	–/–	–/–	–/–	+/–	+/–	–/–	–/–	–/–
African Grey Parrot	–/–	+/+	–/–	+/–	–/–	–/–	–/–	–/–
Mallard duck	+/–	+/–	–/–	–/–	–/–	+/–	–/–	–/–
White geese	+/–	–/+	–/–	–/–	–/+	+/–	–/–	–/–
Crowned Crane	+/–	–/+	–/–	+/+	-/–	+/–	-/–	-/–

Key: (-): no ova or cyst found; (+): ova or cyst is present (+): 1-50 eggs per gram (epg);

(++): 51-100 epg; (+++): 100-150 epg

Table 3: Mean and standard error of parasite abundance in samples (Rainy season)

	Ostrich	**Geese**	**Grey parrot**	**African crowned Crane**
Ascaris spp	40.75± 1.55	-	-	-
Entamoeba spp	36.00± 12.00	33.75± 11.39	21.50± 12.42	33.7±1.79
Giardia spp	-	-	-	12.75± 4.33
Ancyclostoma spp	47.25± 0.85	38.00± 2.08	-	-

Quantitative analysis of parasite abundance in captive birds

The mean abundance and standard error of gastrointestinal parasite egg counts across bird species are presented in Tables 3 and 4, corresponding to the rainy and dry seasons respectively. These values offer a detailed perspective on the intensity of infection across different host species and time periods. During the rainy season (Table 3), ostriches exhibited notably high burdens of Ascaris spp (40.75 ± 1.55 EPG), Entamoeba spp (36.00 ± 12.00 EPG), and Ancyclostoma spp (47.25 ± 0.85 EPG), indicating substantial helminthic and protozoan parasitism in this species. Geese also presented considerable loads of Entamoeba spp (33.75 ± 11.39 EPG) and Ancyclostoma spp (38.00 ± 2.08 EPG), while African Grey Parrots were infected with Entamoeba spp (21.50 ± 12.42 EPG). The presence of Giardia spp was most prominent in African Crowned Cranes (12.75 ± 4.33 EPG), reflecting a possible role of water or moist environments in transmission.

In the dry season (Table 3b), ostriches maintained a consistently high parasite load, with Ascaris spp (61.00 ± 1.41 EPG), Entamoeba spp (17.00 ± 1.83 EPG), and Strongyloides spp (34.25 ± 1.89 EPG) dominating the profile. This persistence across seasons underscores the continuous exposure of ground-foraging species like ostriches to contaminated environments, possibly due to enclosure substrate and hygiene challenges. Mallard Ducks also recorded substantial levels of Ascaris spp (17.00 ± 0.82 EPG), Entamoeba spp (15.25 ± 0.50 EPG), and Strongyloides spp (7.50 ± 1.00 EPG), indicating moderate infections that align with similar ecological behavior. African Grey Parrots again exhibited notable protozoan burdens with Entamoeba spp (12.50 ± 1.29 EPG) and Giardia spp (10.25 ± 0.96 EPG), supporting their susceptibility to waterborne pathogens.

In other bird species, like Crowned Cranes and White Geese, parasite burdens appeared more varied. Crowned Cranes were infected with Ascaris spp (4.75 ± 1.50 EPG), Strongyloides spp (9.00 ± 0.82 EPG), and Giardia spp (6.25 ± 0.50 EPG), while White Geese recorded Ascaris spp (16.25 ± 2.87 EPG) and Strongyloides spp (16.25 ± 0.96 EPG). Peacocks, on the other hand, had detectable levels of Giardia spp (12.25 ± 0.96 EPG) and Ancyclostoma spp (10.00 ± 0.82 EPG), suggesting a relatively lighter but targeted parasite profile.

Table 4: Mean and standard error of parasite abundance in samples (Dry season)

	Grey parrot	**Crowned crane**	**Mallard duck**	**Ostrich**	**Peacock**	**White gesse**
Ascaris spp	-	4.75±1.50	17±0.82	61.00±1.41	-	16.25±2.87
Entamoeba spp	12.50±1.29	-	15.25±0.50	17.00±1.83	-	-
Giardia spp	10.25±0.96	6.25±0.50	-	-	12.25±0.96	-
Ancyclostoma spp	-	-	-	-	10.00±0.82	-
Strongyloides spp	-	9.00±0.82	7.50±1.00	34.25±1.89	-	16.25±0.96

Tables 3 and 4 present the mean abundance (expressed as eggs per gram, EPG) and standard error of gastrointestinal parasites detected in captive bird species during the rainy and dry seasons, respectively. These quantitative data provide insight into seasonal variations in parasite load among the different avian hosts.

Table 5: T-tests for the different samples and parasites

Parasite	**n(Rainy)**	**n(Dry)**	**t**	**Df**	**p-value**	**Significance**
Ascaris spp	26	28	-3.607	52	0.002	+
Entamoeba spp	26	28	-4.418	52	0.001	+
Giardia spp	26	28	-4.236	52	0.001	+
Enterobius spp	26	28	NaN	52	NaN	NS
Trichuris spp	26	28	NaN	52	NaN	NS

*p<0.05 shows a significant difference in the mean value of parasites found in the animals

Table 5 displays the results of independent sample t-tests conducted to assess statistical differences in mean parasite burdens between the rainy and dry seasons. It includes sample sizes (n), t-values, degrees of freedom (df), p-values, and significance levels for each parasite analyzed. Significant seasonal differences ($p < 0.05$) are highlighted.

3.3 Statistical significance of seasonal differences in parasite burden

Table 5 presents the statistical results from independent sample t-tests assessing differences in the mean parasite burdens between the rainy and dry seasons among all bird species. Significant seasonal variations were observed for several parasites.

Specifically, Ascaris spp showed a statistically significant difference with a t-value of -3.607 and a p-value of 0.002, indicating higher prevalence in one season over the other. Similarly, Entamoeba spp ($t = -4.418$, $p < 0.001$) and Giardia spp ($t = -4.236$, $p < 0.001$) also exhibited significant differences, suggesting a notable seasonal influence on the distribution and intensity of these protozoan infections among birds. Conversely, no

significant differences were observed for Enterobius spp and Trichuris spp, as indicated by undefined t- and p-values (NaN), due to the absence of these parasites in both seasons. These results suggest that these particular parasites were either absent or undetectable in the fecal samples analyzed, hence not contributing to seasonal variability.

Overall, the statistical outcomes reinforce the conclusion that seasonal variation significantly affects the prevalence and intensity of certain gastrointestinal parasites in captive birds at the FUNAAB Zoological Garden. The significant p-values provide robust evidence that the observed differences are not due to random variation but rather reflect really ecological and biological differences driven by season.

Discussion

This study investigated the seasonal variation in gastrointestinal parasite prevalence among captive birds housed at the FUNAAB Zoological Garden in Ogun State, Nigeria. The analysis focused on comparing parasite presence, abundance, and statistical significance across rainy and dry seasons to better understand the environmental and behavioral factors influencing parasite dynamics in avian hosts. The overall results demonstrated a distinct seasonal influence on the occurrence and abundance of gastrointestinal parasites. Species such as ostrich, geese, and mallard ducks exhibited higher parasite burdens in the rainy season, which is consistent with earlier findings by (Egbetade et al., 2014), who reported increased parasite transmission rates in wetter environments due to favorable conditions for egg development and larval survival. The observed seasonal variation is likely a result of increased humidity and moisture, which facilitate the survival and transmission of infective stages of helminths and protozoans in the environment.

The most frequently encountered parasites across bird species included Ascaris spp, Entamoeba spp, Giardia spp, and Ancyclostoma spp. These parasites have been documented in captive and semi-captive avian populations, especially in settings where hygiene and environmental control may fluctuate between seasons (Clayton and Moore, 2017; Fowler and Miller, 2020). The predominance of protozoan infections, particularly Giardia and Entamoeba, during the rainy season can be attributed to increased fecal-oral transmission through contaminated water and surfaces, supporting the epidemiological findings of Forbes et al. (2019) and Hudson et al. (2016).

Statistical analyses confirmed significant differences in the prevalence and abundance of most parasites between the rainy and dry seasons. For instance, the mean egg per gram (EPG) values of Giardia spp and Ancyclostoma spp were significantly higher in peacocks and grey parrots during the rainy season. T-test results supported these findings, with p-values well below the significance threshold ($p < 0.05$), indicating a true difference in infection levels rather than random variation. These results align with those of Tompkins et al. (2018), who emphasized that seasonal changes can affect parasite-host dynamics, especially in species exposed to open or semi-controlled environments.

These quantitative patterns suggest that while seasonal variations play a significant role in shaping parasite survival and transmission, the host's behavioral ecology particularly factors such as feeding behavior, ground contact, and water source exposure also strongly influences infection intensity. The consistently high values in ostriches and other ground-foraging birds support the notion that enclosure design and environmental management are central to parasite control. These findings are consistent with Fowler and Miller (2020), who reported increased parasite loads in zoo birds during specific seasons, and Clayton and Moore (2017), who emphasized the roles of habitat type, sanitation, and interspecies differences in determining parasitic burden in captive avian populations.

Interestingly, while most bird species showed higher parasitic loads in the rainy season, a few, such as the African crowned crane, had relatively stable infection levels across both seasons. This could be attributed to differences in grooming behavior, dietary selectivity, and enclosure conditions. Moreover, the absence or non-significant results for certain parasites (e.g., Enterobius spp, Trichuris spp) may reflect species-specific resistance or environmental conditions that do not favor their life cycle in avian hosts. This study's approach, integrating descriptive statistics with inferential tests such as ANOVA and t-tests, allowed for a rigorous comparison of parasite burdens between seasons. It provides valuable insights into zoo bird health management and offers a basis for tailored deworming schedules and sanitation protocols during high-risk periods.

Furthermore, recent studies have increasingly emphasized the role of environmental persistence and anthropogenic factors in shaping parasite transmission dynamics in captive wildlife systems. For instance, Akinsanya et al. (2021) and Otegbade et al. (2022) reported that inadequate enclosure sanitation, high stocking density, and poor waste management significantly enhance the accumulation and dissemination of infective parasite stages in zoological settings. This is particularly relevant to the present study, where consistently high parasite loads observed in

ostriches across both seasons may be linked not only to their ground-foraging behavior but also to repeated exposure to contaminated substrates within confined enclosures.

In addition, the persistence of Ascaris spp. and Strongyloides spp. across seasons, as observed in this study, corroborates findings from more recent parasitological surveys in captive avifauna, which highlight the resilience of helminth eggs and larvae under varying environmental conditions (Mwangi et al., 2020; Ibrahim et al., 2023). These parasites possess resistant developmental stages capable of withstanding desiccation and moderate temperature fluctuations, thereby maintaining infectivity even during less favorable dry periods. This could explain the sustained high egg per gram (EPG) values recorded in ostriches during the dry season.

Moreover, the detection of protozoan parasites such as Giardia spp. and Entamoeba spp. in both seasons aligns with recent reports emphasizing the zoonotic and environmental health significance of these organisms. Studies by Ahmed et al. (2021) and Li et al. (2022) have demonstrated that protozoan cysts can remain viable in water sources for extended periods, particularly in poorly managed captive environments. The repeated occurrence of these protozoa in African Grey Parrots and Crowned Cranes in this study further suggests the role of contaminated drinking water and feeding systems as critical transmission pathways.

Another important consideration is the influence of climate variability on parasite epidemiology. Recent global and regional assessments (e.g., Adeyemi et al., 2022; WHO, 2023) indicate that fluctuations in rainfall patterns and temperature associated with climate change are increasingly altering the distribution and intensity of parasitic infections in both wild and captive animal populations. The significant seasonal differences observed in Ascaris, Entamoeba, and Giardia infections in this study therefore reflect broader ecological trends, where wetter conditions enhance parasite development, while dry conditions may not completely eliminate infective stages but rather reduce their transmission efficiency.

Importantly, the findings of this study also have implications for One Health, an interdisciplinary approach that links animal, human, and environmental health. The presence of zoonotic parasites such as Giardia spp. and Ancylostoma spp. in captive birds raises concerns about potential transmission to zoo personnel and visitors, particularly in settings with close human–animal interaction. Recent literature (Centers for Disease Control and Prevention [CDC], 2022; Thompson, 2021) underscores the need for integrated surveillance and hygiene practices in zoological gardens to mitigate zoonotic risks.

To further strengthen parasite control strategies, recent recommendations advocate for routine fecal monitoring using quantitative techniques such as EPG, strategic deworming based on infection thresholds, and improved enclosure hygiene (Zajac and Conboy, 2021; Permin and Hansen, 2020). The incorporation of EPG values in this study provides a more robust assessment of infection intensity and supports evidence-based decision-making in parasite management.

Overall, the integration of seasonal, ecological, and quantitative parasitological data in this study contributes to a growing body of evidence highlighting the complexity of parasite dynamics in captive bird populations. Future studies should consider incorporating molecular diagnostic tools for parasite identification, as well as longitudinal monitoring to better understand temporal trends and intervention outcomes.

Conclusion

The findings underscore the impact of seasonality on gastrointestinal parasite prevalence and intensity in captive wild birds. The higher infection rates during the rainy season call for increased surveillance and proactive veterinary intervention during this period. Ensuring consistent sanitation, routine fecal screening, and strategic anthelmintic administration are critical in mitigating parasitic risks and promoting avian welfare in zoological settings.

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