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Endo-Parasites of Apparently Healthy Wild Birds in Kaduna State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AA and AS designed the study. Authors AE and AS captured and identified the birds. Author AA performed the statistical analysis. Authors AA and PA wrote the protocol and the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Wildbirds interaction with poultry increases the likelihood of exchange of parasites between wild birds and poultry highlighting the need to understand wild bird endoparasites to reduce cross-infection at the wild bird-poultry interface. This study investigates the prevalence and diversity of endoparasites among wild birds in Kaduna State to provide baseline data on the wild birds' endoparasites which could be a source of infection to poultry.
Study Design: Wild birds in live wild bird markets, free-flying wild birds and semi-domesticated birds were the samples for endoparasites.
Place and Duration of Study: Birds were sampled in Kaduna State, Nigeria and the samples were analyzed at the helminthology laboratory of Ahmadu Bello University, Zaria between April 2012 and December 2012.

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Methodology: Wild birds faecal samples were examined for endoparasites by the simple flotation method.
Results: Of the 357 birds sampled, 36.4% were infected with at least one species of endoparasite. Charadriidae (7.1%) and *Meleagris gallopavo* (23.5%) had the lowest family and species prevalence respectively. Free flying, live poultry markets (LPM) and live wild bird markets (LWBM) birds had a prevalence of 39.1%, 37.2% and 34% respectively. The endoparasites identified were coccidia (30.5%), *Ascaridia* (5.9%), nematode larvae (0.8%), *Capillaria* (0.6%); *Syngamus*, *Raillietinia* and *Trichuris* (0.3% for each). There was a significant difference between the prevalence (p = 0.00), mean intensities (p = 0.00) and abundance (p = 0.01) of coccidia and *Ascaridia*. The prevalence of multiple infections was 2.0% representing 5.4% of infected birds. The study is first to report in Kaduna State, Nigeria of *Trichuris* in *Anas platyrhynchos* and *Raillietina* in *Laniarius barbarous*.
Conclusion: Wild birds in Kaduna State, Nigeria harbours endoparasites of economic significance to poultry and there is the need for more study of these wild birds' endoparasites at the wild bird–poultry interface.

Keywords: Anas platyrhynchos; endoparasite; Kaduna State; Laniarius barbarous; Raillietina; Trichuris; wild bird.

1. INTRODUCTION

Wild birds are an essential component of an ecosystem and they interact with poultry, humans and other livestock with the likelihood of exchange of parasites between wild birds and livestock [1]. Parasites are abundant in wild birds with an individual bird likely to be infected by different parasites during their lifetime though reports of clinical disease due these parasites are usually rare in healthy individuals in the wild [2]. However, parasites usually cause severe distress and infections in captive wild birds, especially those kept under crowded and poor sanitary conditions [3].

In Nigeria, wild birds hunted for food and aesthetic reason are sold in live wild bird markets (LWBM) and raised in captivity thus increasing the stress on the birds and the wild bird-human interaction [4]. Increased urbanization leading to encroachment into wildlife habitats has increased wild birds' dependence on human activities for food, as they visit poultry and newly tilled farms to feed on spilt poultry feed/seeds or other livestock materials within farms [5].

The understanding of the endoparasites infecting wild birds in Nigeria is fragmentary due to inadequate baseline information about the host species with a rudimentary knowledge of the wild bird life-history traits [6]. This has led to the extrapolation from other species especially poultry in a bid to understand the relationship between wild birds and their endoparasites. There is a need to identify the endoparasites in a wild bird to reduce cross-infection at the wild bird-livestock interface.

This study investigated the prevalence and diversity of endoparasites among wild birds in three epidemiologic units through morphologic identification and evaluated the patterns of infection.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Kaduna State, located in North-Western Nigeria between latitude 8°45''- 11°30" North and longitude 6°11" – 9°East [7]. It shares a boundary with Kastina, Kano, Plateau, Niger, Zamfara, Bauchi, Nassarawa and FCT and has 23 local government areas that are inhabited by ethnic groups including Hausa, Fulani, Kaje and Kataf amongst others. Kaduna State has a population of 6 million people and 2,821,092 poultry of which 90% is local poultry raised extensively [7].

The annual temperature is 34°C with hottest months being March-April (40°C) and the coolest period (13.2°C) being December during severe harmattan. Rainfall varies between 1,000 mm and 1,500 mm and the rainy season lasts 100-150 days (Mid April – ending of October). The dry season occurs between October and April [7]. Kaduna State has a land structure of undulating Plateau with major rivers including River Kaduna, River Wonderful in Kafanchan,

River Kagom, River Gurara and Galma [7]. The vegetation varies from the Guinea Savannah in the south to the Sudan Savannah in the North [7].

2.2 Sampling Technique

Wild bird in LWBMs, free-flying and semi-domesticated birds from live poultry markets (LPMs) were sampled during the study. Four sampling locations were chosen based on poultry density, presence of LWBMs and LPMs; water bodies.

The sample size for the study was not pre-determined due to lack of information on the prevalence rate of ectoparasites in Kaduna State and the inability to estimate the population of wild birds in Kaduna State. A targeted sampling was done. All birds sampled (except roasting birds) were marked using a permanent marker to avoid multiple sampling of the same bird.

2.3 Sampling Units

Wild birds were sampled from three epidemiologic units namely live wild bird markets (LWBMs), free-flying wild birds and live poultry markets (LPMs).

2.3.1 Live wild bird market

Live wild birds in Kaduna LWBMs were sampled after live wild bird sellers in Kaduna LWBMs were approached and consent obtained for participation in the study.

2.3.2 Free flying wild birds

Free flying birds are wild birds that were not in captivity. The birds were captured by mist nets, hunting and use of other traps. Hunters gave consent for hunted birds to be sampled. For free-flying wild birds roosting on trees, faecal samples were collected by the use of a white paper. Free flying wild birds were sampled from Kaduna, Samaru, Anchau, Karoye and Sabon Gari.

2.3.3 Live poultry markets

Two semi-domesticated species – guinea fowls and mallard ducks were identified due to their arboreal nature and likelihood of interacting with wild birds especially migratory birds and local poultry in human habitats. Live mallards and guinea fowls were sampled from Anchau LPM after obtaining consent from sellers to sample birds.

2.4 Identification of Wild Bird

Wild birds roasting on trees whose faecal samples were collected were also identified using a pair of binoculars with magnification 7x 50. All birds were visually identified with the aid of a field guide by Borrow and Demey [8] and physically examined before sampling.

2.5 Faecal Sample Collection

Fresh faecal samples were collected from identified wild birds using swab sticks into labelled tubes. Faecal droppings of roasting wild birds were also collected after identification of the bird species.

All faecal samples were individually collected and stored in insulated clean tubes which were labelled with bird species, field number and date. The samples were then preserved in a cooler before being transported to the laboratory and stored in the fridge at +4°C until analyzed.

2.6 Identification of Endoparasites in Faecal Sample

The faecal samples collected were examined for helminthes eggs, coccidia oocytes and other intestinal parasites by the simple flotation method. Briefly, a sodium chloride-sucrose solution was used as the washing and diluting medium which concentrates the parasites on the surface which were collected on microscope cover-slips and viewed under a microscope in the Helminthology Laboratory of the Department of Veterinary Parasitology and Entomology, Ahmadu Bello University Zaria, Nigeria. Slides were microscopically screened at 100X and 400X magnifications and parasites are seen were identified by their morphometric characteristics and documented by photography [9].

2.7 Data Analysis

The positive bird was defined as any wild bird with at least one endo-parasite. Prevalence, mean intensity and mean abundance values were analysed using Quantitative Parasitology 3.0 [10].

The differences in prevalence between endo-parasites, was determined using chi square test. The difference in mean intensity and abundance between parasites was determined using t-test. The median intensities were compared using Mood's median test [10]. Confidence intervals for prevalence and intensity were computed using Sterne's exact method, and bootstrapping (with 2,000 repetitions), respectively, using the computer program Quantitative Parasitology 3.0 [11].

Prevalence between and within families, species, epidemiologic units and sampling sites, were compared by the chi-square test with p values ≤ 0.05 considered significant. Association of endo-parasite and other parameters were analyzed using cross-tabulations with Statistical Package for Social Sciences (SPSS) version 17.

3. RESULTS AND DISCUSSION

3.1 Results

Of the 357 birds sampled in this survey, 36.4% (130/357) were infected with at least one species of internal parasites. The parasites were coccidia oocytes, nematode larvae, *Ascaridia*, *Syngamus*, *Trichuris* and *Raillietinia* and *Capillaria* eggs (Plate 1).

The prevalence for *Coccidia oocytes* was 30.5% (109/357) at 95% confidence limits (CL) of 25.1 – 35.9% with a mean intensity and abundance of 12.24 (95% CL of 11.41 - 13.06) and 3.70 (95% of 2.99 - 4.45) respectively. *Ascaridia* eggs prevalence was 5.9% (21/357) with CL of 4.8 - 1.1 at 95% confidence interval with a mean intensity and abundance of 10.5 (95% CL of 10.00 - 11.50) and 0.75 (95% CL 0.43 - 1.07). There was a significant difference between the prevalence (p=0.00), mean intensities (p=0.00) and abundance (p=0.01) of coccidia oocytes and *Ascaridia* eggs. Generally, mild and moderate coccidian oocytes infection prevalence was 24.9% (89/357) and 6.2% (22/357) respectively although among coccidia oocytes infected birds, 81.7% (89/109) were mildly infected with 20.2% (22/109) been moderately infected. The prevalence of other endoparasites encountered in during the study was 0.8% (3/357) for nematode larvae; 0.3% (1/357) for *Syngamus*, *Raillietinia* and *Trichuris* eggs respectively and 0.6% (2/357) for *Capillaria*.

About 77.8% (28/36) families and 67.2% (41/61) species were infected with endoparasites, with *Meleagris gallopavo* had the lowest species prevalence rate of 23.5% (4/17) (Table 1).

Twenty three six had coccidia oocytes infection with prevalence ranging from 9.1% (1/11) for Malaconotidae to 100% for Acciptridae. Similarly, 37 species were infected with coccidia oocytes with a prevalence range of 12.5% to 100%. However, 25% (9/36) of sampled families had *Ascaridia* infection with 11.1% (1/9) of infected families having moderate *Ascaridia* eggs infection (Table 2). Only 6.1% (2/33) of studied families had *Capillaria* eggs infection, with prevalence rates of 3.3% (1/30) for Numididae (Table 3). Nematode larvae were reported in *Vanellus spinosus* and *Amaurornis flavirostra* with species prevalence rates of 50 % (1/2) and 10% (1/10) respectively (Table 3). *Trichuris* eggs were observed only in *Anas platyrhynchos* of the Anatidae family while *Laniarius barbarus* were infected with *Raillietina* (Table 3). Brown Babbler (*Turdoides plebejus*) was the only species infected with *Syngamus*.

The prevalence of multiple endoparasite infection in the study was 2.0% (7/375) representing 5.4% (7/130) of infected birds. However, among birds with multiple endoparasite infection, 57.1% (4/7) had mild *Ascaridia* eggs/mild coccidia oocytes infection, with 14.3% (1/7) having mild coccidia oocytes /moderate *Ascaridia* eggs and 28.6% (2/7) having moderate coccidia oocytes/moderate *Ascaridia* eggs infections.

Endoparasite prevalence in free flying birds was 39.1% (79/202) while the prevalence for LBM and LWBM were 37.2% (16/43) and 34% (35/103) respectively. Coccidia oocyts prevalence in free flying birds was 33.2% (67/202) at 95% confidence limits of 24.4% - 40.3% with mean intensity and abundance of 12.09 (95% CL of 10.93 - 13.26) and 3.85 (95% CL of 2.96 - 4.89) respectively. The LBM and LWBM coccidia oocyts prevalence were 25.6 % (11/43) at 95% CL of 14.6% - 40.6% and 30.1 (31/103) at 95% CL of 21.8% - 39.8 % respectively.

Among the wild bird's infected coccidia oocytes, 63.2% (55/87) free flying birds had mild coccidia infection together with 11.5% (10/87) and 25.3% (22/87) of LPM and LWBM birds. Moderate coccidia infection was 54.2% (12/22) for free flying 40.9% (9/22) for LWBM birds and 4.5% (1/22) for LPM birds.

Table 1. Prevalence of endoparasites among wild birds in Kaduna State, Nigeria (P= 0.00)

Infected Family/Species	P (No. infected/sampled)	**Coccidia** oocyts
Acciptridae	**100% (2/2)**	**100% (1/1)**
Elanus caeruleus	100.0% (1/1)	100.0% (1/1)
Pandion haliaetus	100.0% (1/1)	100.0% (1/1)
Anatidae	**26.9% (7/26)**	**15.4% (4/26)**
Barn geese	23.1% (3/13)	15.4%(2/13)
Anas platyrhynchos	30.8% (4/13)	15.4% (2/13)
Ardeidae	**30.8% (4/13)**	**30.8 (4/13)**
Ardea cinerea	33.3 5 (1/3)	33.3% (1/3)
Bubulcus ibis	33.3% (1/3)	33.3% (1/3)
Egretta alba	33.3% (1/3)	33.3% (1/3)
Ardeola ralloides	25% (1/4)	25% (1/4)
Charadriidae	**7.1% (1/14)**	**35.7% (5/14)**
Vanellus spinosus	50% (4/8)	37.5% (3/8)
Vanellus tectus	66.7% (2/3)	66.7% (2/3)
Ciconiidae	**27.3% (9/33)**	**27.3% (9/33)**
Ciconia ciconia	27.3% (9/33)	27.3% (9/33)
Columbidae	**38.5% (15/39)**	**33.3% (13/39)**
Columba livia	50% (2/4)	50% (2/4)
Streptopelia senegalensis	37.8% (6/16)	37.8 (6/16)
Streptopelia vinacea	50% (2/4)	50% (2/3)
Streptopelia capicola	40% (2/5)	20.0% (1/5)
Streptopelia semitorquata	50% (2/4)	50.0% (2/4)
Corvidae	**100% (2/2)**	**100.0% (2/2)**
Corvus albus	100.0% (1/1)	100.0% (1/1)
Ptilostomus afer	100% (1/1)	100% (1/1)
Cuculidae	**100% (1/1)**	**100 (1/1)**
Centropus senegalensis	100% (1/1)	100 (1/1)
Dicruridae	**100% (1/1)**	**100.0% (1/1)**
Dicrurus adsimilis	100% (1/1)	100.0% (1/1)
Gruidae	**62.5% (5/8)**	**62.5% (5/8)**
Balearica pavonina	62.5% (5/8)	62.5% (5/8)
Hirundinidae	**25% (2/8)**	**12.5% (1/8)**
Hirundo aethiopica	25% (2/8)	12.5% (1/8)
Indicatoriidae	**100% (1/1)**	**100% (1/1)**
Honey guide	100% (1/1)	100% (1/1)
Jacanidae	**33.3% (1/3)**	**33.3% (1/3)**
Actophilornis africanus	33.3% (1/3)	33.3 % (1/3)
Malaconotidae	**15.4% (2/11)**	**9.1 % (1/11)**
Tchagra minutes	100% (1/1)	100% (1/1)
Laniarius barbarous	33.3% (3/9)	22.2% (2/9)
Melagrididae	**17.6% (3/17)**	**17.6% (3/17)**
Meleagris gallopavo	23.5% (4/17)	17.6% (3/17)
Musophagidae	**66.7% (2/3)**	**66.7% (2/3)**
Crinifer piscator	66.7% (2/3)	66.7% (2/3)
Nectariniidae	**22.2% (2/9)**	**22.2% (2/9)**
Chalcomitra senegalensis	28.6% (2/7)	28.6% (2/7)
Numididae	**40% (12/30)**	**30% (9/30)**
Numida meleagris	40% (12/30)	30% (9/30)
Phasianidae	**39.3% (22/56)**	**35.7% (20/56)**
Francolinus bicalcaratus	41.5% (22/53)	35.8% (19/53)
Pavo cristatus	33.3% (1/3)	33.3%(1/3)
Ploecidae	**66.7% (2/3)**	**33.3% (1/3)**
Ploceus cucullatus	66.7% (2/3)	**33.3% (1/3)**

Infected Family/Species	P (No. infected/sampled)	**Coccidia** oocyts
Psittacidae	**100% (1/1)**	**100% (1/1)**
African grey	100% (1/1)	100% (1/1)
Pynonotidae	**52.6% (10/19)**	**52.6% (10/19)**
Pychonotus barbatus	52.6% (10/19)	52.6% (10/19)
Rallidae	**57.9% (11/19)**	**36.8% (7/19)**
Amaurornis flavirostra	66.7% (6/9)	33.3% (3/9)
Porphyrio porphyrio	55.6% (5/9)	44.4% (4/9)
Recurvirostridae	**25% (1/4)**	**25% (1/4)**
Himantopus himantopus	25% (1/4)	25% (1/4)
Rostratulidae	**100% (1/1)**	**0%**
Rostratula benghalensis	100% (1/1)	0%
Slyviidae	**100% (1/1)**	**100% (1/1)**
Slyvia melanocephala	100% (1/1)	100% (1/1)
Timaliidae	**50% (1/2)**	**50% (1/2)**
Turdoides plebejus	50% (1/2)	50% (1/2)
Turdidae	**33.3% (2/6**)	**33.3% (2/6**)
Turdus pelios	33.3% (2/6)	33.3% (2/6)
Total	**36.4% (130/357)**	**30.5% (109/357)**

Table 2. Prevalence of *Ascarida* eggs among wild birds in Kaduna State, Nigeria (p = 0.00; X^2= 389.86)

Infected Family/Species	***Ascaridia* eggs**
Anatidae	**7.7% (2/26)**
Barn geese	7.7% (1/13)
Anas platyrhynchos	7.7% (1/13)
Ardeidae	**16.7% (1/6)**
Ardea cinerea	33.3% (1/3)
Columbidae	**6.9% (2/29)**
Streptopelia vinacea	33.3% (1/3)
Streptopelia capicola	20% (1/5)
Hirundinidae	**12.5% (1/8)**
Hirundo aethiopica	12.5% (1/8)
Melagrididae	**11.8% (2/17)**
Meleagris gallopavo	11.8% (2/17)
Numididae	**10% (3/30)**
Numida meleagris	10% (3/30)
Phasianidae	**10.2% (5/50)**
Francolinus bicalcaratus	8.7% (4/46)
Pavo cristatus	33.3% (1/3)
Ploecidae	**50% (1/2)**
Ploceus cucullatus	100% (1/1)
Pynonotidae	**9.1 (1/11)**
Pychonotus barbatus	9.1 (1/11)
Rallidae	**15.8 (3/19)**
Amaurornis flavirostra	11.1% (1/9)
Porphyrio porphyrio	22.2% (2/9)
Total	**7.1% (20/281)**

The *Ascaridia* eggs prevalence in free flying birds at 95% with CL of 3.4% - 1.2% was 5.0 % (10/202) with a mean intensity and abundance of 11.11 (at 95% CL of 10.00 - 13.33) and 0.74 (at 95% CL of 0.30 -1.26) respectively. *Ascaridia* eggs prevalence in LBM and LWBM were 9.3% (4/43) at 95% CL of 2.6 – 22.1 and 6.8% (7/103) at 95% CL of 3.2 – 13.5 respectively with mean abundance of 0.93 (at 95% CL of 0.23-1.86) and 0.68 (at 95% CL of 0.19-1.17) respectively. *Capillaria* and *Syngamus* were observed only in free flying with prevalence of 0.7% (1/202). *Capillaria* prevalence in LPMs was 2.3% (1/43).

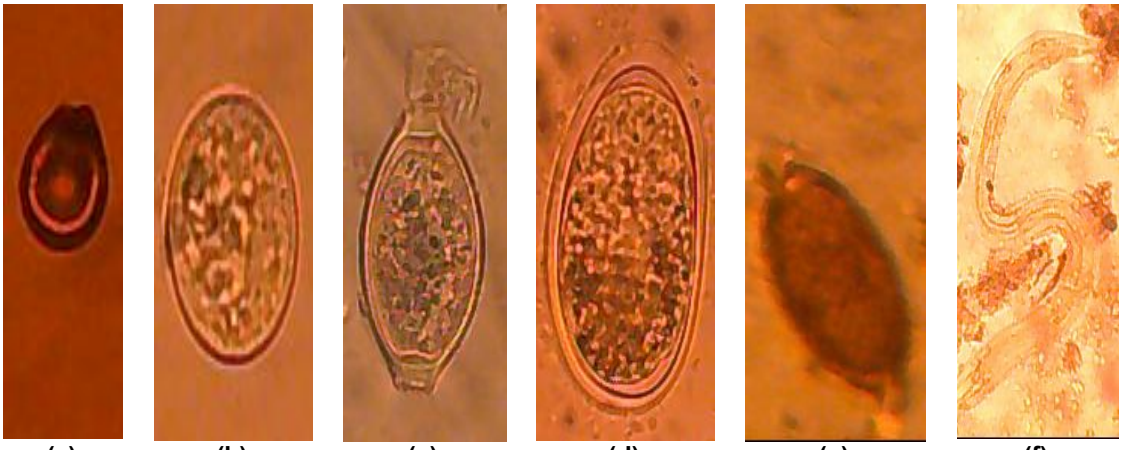

Plate 1. Endoparasites of wild birds in Kaduna State, Nigeria. (a) *Coccidia oocyte* from the grey heron. (b) *Coccidia oocyte* from laughing dove. (c) Tricuris eggs from mallard duck. (d) Ascaridia eggs from purple swamphen. (e) Capillaria eggs from Allen ganulle. (f) Nematode larvae from spur-winged lapwing

Table 3. Prevalence of Nematode larvae, *Capillaria*, *Trichuris* and *Raillietina* among wild birds in Kaduna State, Nigeria (p = 0.00; X^2 = 389.86)

Infected Family/Species	*Capilaria*	*Trichuris*	Nemadode larvae	*Raillietina*
Anatidae	-†	3.8% (1/26)	-	-
Anas platyrhynchos	-	7.7% (1/13)	-	-
Charadriidae	-	-	20% (1/5).	-
Vanellus spinosus	-	-	50% (1/2)	-
Malaconotidae	-	-	-	25% (1/4);
Laniarius barbarous	-	-	-	50% (1/2)
Numididae	3.3% (1/30)	-	-	-
Numida meleagris	3.3% (1/30)	-	-	-
Rallidae	5.3% (1/19)	-	5.3% 1/19);	-
Amaurornis flavirostra	11.1% (1/9)	-	11.1% (1/9)	-
Rostratulidae	-	-	100% (1/1)	-
Rostratula benghalensis	-	-	100% (1/1)	-

†= Negative

Endoparasite prevalence within sampling sites were 38.4% (28/73) in Anchau, 33.6% (36/107) in Kaduna, 38% (62/160) in Samaru; 50% (2/4) in Koraye and 33.3% (2/6) in Sabon Gari. However, between locations, endoparasite prevalence was 21.5% (28/130) in Anchau, 27.7% (36/130) in Kaduna, 47.7% (62/130) in Samaru; and 1.5% (2/130) in Sabon Gari and Koraye.

The coccidia oocyts prevalence in Anchau and Kaduna were 28.8% (21/73) at 95% CL of 19% – 40.4% and 29.0% (31/107) at 95% CL of 20.9% – 38.3%. However, their mean intensities and abundance were 11.4 (at 95% CL of 10-12.86) and 3.29 (at 95% CL of 2.1-4.7) and 12.9 (at 95% CL of 11.3-14.2) and 3.74 (at 95% CL of 2.7-5.0) respectively. *Coccidia oocyts* prevalence in Samaru was 33.5% (53/158) at 95% CL of 23% – 42.3% and with mean intensities and abundance of 11.7 (at 95% CL of 10.3 - 12.8) and 3.74 (at 95% CL of 2.6-5.0) respectively.

The Ascaridia eggs prevalence were 9.6% (7/73) in Anchau, 7.5% (8/107) in Kaduna and 3.4% (6/158) in Samaru. However, among birds infected with Ascaridia, 33.3% (7/21) were from Anchau, 38.1% (8/21) from Kaduna and 28.6% (5/21) from Samaru. Although, capillaria eggs were observed in Anchau and Samaru, 1.9% (3/158) and 0.6 (1/158) of the birds in Samaru were infected with nematode larvae and Raillietina respectively. Also, 1.4% (1/73) of the

birds sampled in Anchau was infected with Trichuris eggs.

3.2 Discussion

The study revealed that five types of endoparasites were prevalent in wild birds in Kaduna State. The parasites were a protozoan (coccidian), three nematodes (*Ascaridia*, *Trichuris* and *Capillaria*) and a cestode (*Raillietina*). Most studies on endoparasites of wild birds investigated a single species of birds and the prevalence varies with most reporting a higher prevalence than was observed in the present study [4,12].

The study further revealed that though wild birds were infected with coccidia and *Ascaridia*, the infection was mild. Among the endoparasites found, coccidia was more abundant but with a lower prevalence compared to previous studies [13]. However, the absence of clinical coccidiosis in these wild birds is probably due to repeated exposures to a few oocytes, which resulted in the development of immunity [14].

The coccidia infection in these wild birds may negatively affect their physical appearance by reducing the signalling value of morphological traits, and behaviour [15,16,17,18]. Likewise, due to the presumed strict host specificity of the avian species of coccidia, these coccidias might not be a threat to unrelated poultry species, though the mixing of wild birds of different species should be discouraged [19]. Conversely, there are reports of possible infection of wild birds such as Passerines with coccidia which might subsequently serve as a potential source of infection to poultry [12].

The families with high endoparasite prevalence are members of the orders Anseriformes and Galliformes which have the highest reported species of coccidia and other endoparasites [19]. These birds are also closely related to poultry species implying the increased likelihood of cross-infectioncross-infection from poultry to wild birds and vice-versa.

This is the first report of *Trichuris* egg in Mallard duck in Nigeria. The duck is likely to have been infected when foraging in areas contaminated with *Trichuris* infected human or dog faeces. However, failure to identify the *Trichus* species is a limitation of the study. This finding might either an indication of active infection of the duck by *Trichuris* or mere passage of the eggs through the duck gut after ingestion since ducks are not the definitive host of *Trichuris* [9]. However, an active infection with eggs producing *Trichuris* in duck implies adaptation of *Trichuris* in ducks, a new host which is worrisome with the possible public health consequence [20].

The study revealed the prevalence of multiple infection contrary to previous studies within the same study area involving francolins, weaver birds and doves [4,21,13]. The difference in prevalence is likely due to previous work determining endoparasite prevalence based on the presence of the parasite unlike the current study in which is based on the presence of eggs and oocytes. However, the amount of eggs or oocytes produced depends on the developmental stage of the parasites, the interaction of the different parasites within a host and the fecundity of the parasite [17]. Wild birds with multiple infections are likely to experience increase immune system activation with resultant increased production of free radicals which significantly affects the wild birds', immunity against and resistance to infection [22,23].

The high intensity and abundance of coccidia in LWBM might be due to confinement of birds in cages resulting in continuous exposure to the coccidia oocyte though the development of resistance by the birds limits the infection. The continuous exposure to coccidia oocyte results in a chronic low-grade infection which stimulates the immune system resulting in increased blood bactericidal activity with high WBC concentration [24].

The study further revealed that birds from LPM are more likely to be infected with *Ascaridia* than free flying and LWBM birds. This is probably because though LPM and LWBM birds are confined resulting in exposure from infected wild birds and contaminated pens. LWBM birds are usually administered anti-helminthics due to their high financial value unlike LPM birds. However, free flying birds which are not confined are spared from re-infection associated with contaminated confined pens [17].

The low *Capillaria* prevalence in this study compared to other studies is likely due to the very low-intensity infections and low fecundity of *Capillaria* with a resultant underestimation of *Capillaria* true prevalence [19]. However, co-infections with multiple Capillarid species may be missed as Capillarid species cannot be identified by egg morphology [19].

The high endoparasite prevalence in Samaru might be due to high density of backyard poultry in Samaru with poor biosecurity practices which increase wild bird-poultry interaction with wild bird infection. Similarly, other anthropogenic activities such as farming with the use of unprocessed poultry manure as fertilizers are likely to increase wild bird endoparasitic infection in Samaru.

4. CONCLUSION

This study confirms that wild birds in Kaduna state are infected with endoparasites and increase in anthropogenic activities is likely to alter the wild bird–endoparasite interaction. Coccidia are the most prevalent endoparasite of wild birds in Kadunia State. The study provides baseline data on wild bird endoparasites and their prevalence within free flying, LWBMs and LPMs in Kaduna State, Nigeria. It also highlights the need for more study of endoparasites of wild birds and their interaction at the wild bird–poultry interface Nigeria.

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CONSENT

As per international standard written consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard written ethical permission has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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