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Avian Haemosporidian Parasites in Domesticated Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria

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Abstract

Avian haemosporidian infections are widespread and can result in the decline of populations or extinction of birds' species. This study aimed to determine the prevalence of avian haemosporidian parasites in 570 rock doves sampled from household and live birds markets from Gombe State, Nigeria. Blood samples were microscopically examined for the presence of haemoparasites, and the overall prevalence of avian haemosporidiosis was 41.8%. The prevalence of haemosporidian was significantly higher ($P < 0.0001$; $\chi 2 = 16.665$) in doves from live birds' markets (25.8%) compared to households (25.8%). Prevalence was also higher ($P = 0.2027$; $\chi 2 = 1.623$) in female (22.3%) compared to male (19.5%) doves. Out of the 238 infected doves, 82 (14.4%) were infected with *Haemoproteus*, 58 (10.2%) with *Plasmodium* and 40 (7.0%) with *Leucocytozoon* species. 25 doves (4.4%) had mixed infection with *Haemoproteus* + *Plasmodium* species, 21 (3.7%) had mixed *Leucocytozoon* species + *Plasmodium* species infections while 12 (3.7%) had mixed *Haemoproteus* + *Plasmodium* + *Leucocytozoon* species infections. Prevalence of all avian haemosporidian species were higher ($P > 0.05$) in doves sampled from live birds' markets compared to those from households, and all avian haemosporidian species except *Leucocytozoon* species were higher ($P > 0.05$) in female than in male doves. It is recommended that awareness campaign to educate the poultry farmers and sellers on how to improve management practices is necessary so as to prevent widespread transmission of the haemosporidian parasites amongst domesticated birds.

Keywords: Rock Doves; Avian Malaria; Haemosporidian Parasites; Gombe State; Nigeria

Introduction

Poultry farming is a significant part of many agricultural societies in developing countries around the world [1,2]. Several studies on the benefits of poultry production carried out in many developing countries have demonstrated its importance to humanity's survival [3-5]. Poultry production generates a higher financial benefit and income in the form of cash from the selling of live birds and eggs than ruminants or pigs, alleviates poverty, and provides high quality animal protein that reduces hunger, enhances nutritional status, and provides food security for rural dwellers when used as food (meat and eggs) [5-8]. Generally, chickens (*Gallus domesticus*), guinea fowls (*Numida meleagridis galeatapallas*), ducks (*Anas platyrhynchos*), pigeons (*Columba livia domestica*), geese (*Anser anser domesticus or Anser cygnoides*), ostriches (*Struthio camelus*), and other domesticated avian species kept around the world are all considered poultry [9]. Pigeons of the Columbiformes order are common and can be found in almost every town and city on the planet [10,11]. The

domestic pigeon (*Columba livia domestica*) is a subspecies of the world's oldest domesticated bird, the rock dove (*Columba livia*), and is usually sold or traded in Nigerian live bird markets to supplement income and animal protein [12]. During wartime, pigeons and doves were used as messengers, and they are now still kept as pets [13]. Unfortunately, their interactions with humans and other domestic and wild birds suggest that they may be potential reservoirs for a variety of poultry parasitic diseases, as well as play a role in the transmission of certain zoonoses to humans [12,14].

Various parasites that spend a significant portion of their lives inside (endoparasites) or on another form of host (ectoparasites) have an effect on pigeon growth, development, and productivity, and may even cause death [15,16]. When exposed to infected bloodsucking dipteran insect bites, haemosporidians infect a wide variety of vertebrate species. It is estimated that 68 percent of all bird species are vulnerable to haemosporidians [17,18]. Doves can be predisposed to parasitic infections due to insufficient health care, poor management and husbandry programs, and insufficient biosecurity. The three most common avian haematozoa genera found in birds are *Leucocytozoon*, *Plasmodium* and *Haemoproteus* (Phylum: Apicomplexa; and Order: Haemosporida) [19,20]. These haemoparasite genera have been identified as the primary cause of avian malaria in infected birds all over the world [21]. Furthermore, larval microfilariae, a form of Filarioid nematode, are haemoparasites found in a variety of organs and tissues of many terrestrial vertebrates, including birds [22,23]. Mosquitoes (*Culicidae*) transmit *Plasmodium,* while biting midges (*Ceratopogonidae*) transmit *Haemoproteus,* and black flies transmit *Leucocytozoon* [19]. Numerous studies on the occurrence, prevalence, and incidence of haemoparasites in domesticated birds have been conducted in Nigeria, but there is little knowledge on the presence of the haemosporidian in domesticated doves. The current study aimed to establish haemoparasite genera in rock doves from Gombe State, Nigeria, because there is limited knowledge of avian malaria parasites among rock doves in the study region.

Materials and Methods

Study Area

This research was carried out in Gombe State, Nigeria, in a few selected LGAs. According to the National Population Commission's 2006 population census, Gombe State, which is situated between latitudes 9°30' and 12°3' N and longitudes 8°45' and 11°45' E, has a population of 2.4 million citizens. The state is located in Nigeria's north-eastern region, bordering Bauchi, Taraba, Adamawa, Yobe, and Borno states. Eleven Local Government Areas (LGAs) in the state are home to ethnic groups such as Hausa, Fulani, Tera, Waja, Tangale, and Bolawa. Crop and livestock cultivation are favored by the state's climatic and edaphic influences.

Study Design

A cross-sectional survey using convenient sampling techniques was conducted in five (5) Local Government areas of Gombe State to collect blood samples from adult domestic rock doves of both sexes from households and live bird markets. Microscopic analysis of thin blood film and buffy coat smears for the presence or absence of intracellular and extracellular blood parasites was performed in this study.

Blood Sample Collection and Analysis

Blood samples were obtained aseptically from adult doves of both sexes by gently jabbing the brachial vein of each dove with sterile 23 gauge needles on site of sample collection after approval from their owners and humane physical restraint. About 50µL of blood samples were tapped into unheparinized capillary tubes as previously stated by Sehgal, et al. [24]. Two separate thin blood smears were made from each blood sample at the point of collection on clean, dry, and grease-free slides, then allowed to air dry for a few minutes before being fixed in absolute methanol and air dried again before properly labeling each slide. The slides were carefully packed and arranged in slide boxes for transport to the Department of Veterinary Parasitology and Entomology Research Laboratory at the University of Maiduguri in Borno State, Nigeria. Thin smears of buffy coat from centrifuged blood samples were also made in the laboratory on a clean dry slide, air dried for a few minutes, fixed in absolute methanol, and air dried again.

Microscopic Detection of Avian Haemosporidian Parasites

The slides were stained for 50 minutes with Giemsa stain (pH 7.2), gently raised with distilled water, and air dried. At low and high magnification oil immersion objectives, thin blood films and buffy coat smears were examined under an Olympus® compound microscope for the presence of intracellular and extracellular parasites. The blood parasites were discovered were compared to dove and pigeon haemoparasites previously described by Bennett and Pierce and Cheesbrough [25,26].

Data Analysis

Data analysis was performed using GraphPad Prism software (GraphPad Inc., San Diego, CA). Prevalence rates were calculated as percentages of proportion. Chi-squared test was used to compare the prevalence between the two sample locations (households and live birds' markets)

and sex (male and females). Differences were considered significant for *P*-values equal to or less than 0.05.

Results

Table 1 shows the result of Overall Prevalence of Avian Malaria Parasites in Domestic Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria. Out of the total five hundred and seventy (570) doves examined, avian malaria parasites was detected in 238 doves, with an overall prevalence rate of 41.8% (95% CI=37.8%-45.8%). Table 2 shows the prevalence of avian malaria parasites in domestic Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria, according to study location and dove sex. Doves sampled from live bird markets (25.8%; 95% CI=22.4%-29.5%) had a higher prevalence of avian malaria parasite infections than those sampled from households (25.8%; 95% CI=22.4%-29.5%). There was a significant (P <0.0001; χ^2=16.665) association between the prevalence of avian malaria parasite infections and the location of the samples collections. Female (22.3%; 95% CI=19.1%-25.9%) doves had a higher prevalence of avian malaria infections than male (19.5%; 95% CI=16.4%-22.9%) doves. However, there was no statistically significant (P = 0.2027; χ^2 = 1.623) difference in prevalence rates between the sexes.

Number of doves examined	Number (%) of doves infected	Prevalence (%)	95% CI
			LL-UL
570	238 (41.8)	41.8	37.8-45.8

Table 1: Overall Prevalence of Avian Malaria Parasites in Domestic Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria.

Parameters	Information	Number of doves examined	Number (%) of doves infected	Prevalence (%)	95% CI	p-value	χ^2	OR	RR
					LL-UL				
Study location	Households	270	91 (33.7)	16.0[a]	13.2-19.2	<0.0001	16.665	2.047	1.353
	Live birds Markets	300	147 (49.0)	25.8[b]	22.4-29.5				
	Overall	570	238 (41.8)	41.8	37.8-45.8				
Sex	Male	285	111 (38.9)	19.5[a]	16.4-22.9	0.2027	1.623	0.7936	0.874
	Female	285	127 (44.6)	22.3[a]	19.1-25.9				
	Overall	570	238 (41.8)	41.8	37.8-45.8				

Table 2: Prevalence of Avian Malaria Parasites in Domestic Rock Doves (*Columba livia domestica*) based on sex and study locations in Gombe State, Nigeria.
Key: CI = Confidence Interval; LL-UL = Lower Limit-Upper Limit; χ^2 = Chi-square OR = Odd ratio; RR = Relative Risk.
[a,b] Different superscripts indicate significant (p < 0.05) difference in prevalence.

Type of Infection	Avian Malaria Parasites Encountered	No. of Doves infected N = 570	Prevalence (%)	95% CI
				LL-UL
	Haemoproteus spp.	82	14.4	11.8-17.5
Single	*Plasmodium* spp.	58	10.2	8.0-12.9
	Leucocytozoon spp.	40	7	5.2-9.4
	Haemoproteus spp. + *Plasmodium* spp.	25	4.4	3.0-6.4
Mixed	*Leucocytozoon* spp. + *Plasmodium* spp.	21	3.7	2.4-5.6
	Haemoproteus spp. + *Plasmodium* spp. + *Leucocytozoon* spp.	12	2.1	1.2-3.7
Overall		238	41.8	37.8-45.8

Table 3: Avian Malaria Parasites Genera Detected in Domestic Rock Doves (Columba livia domestica) in Gombe State, Nigeria.
Key: N = Number of doves examined; LL - UL = Lower Limit-Upper Limit; CI= Confidence Interval.

The results of the genera of avian malaria parasites discovered in domestic Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria are shown in Table 3. The results showed that *Haemoproteus* species (14.4%; 95% CI = 11.8%-17.5%) infection is more prevalent than *Plasmodium* (10.2%; 95% CI = 8.0%-12.9%) species or *Leucocytozoon* (7.0%; 95% CI=5.2%-9.4%) species infection. However, mixed infections of *Haemoproteus* species + *Plasmodium* species (4.4%; 95% CI = 3.0%-6.4%) infections are more prevalent, followed by *Leucocytozoon* species + *Plasmodium* species (3.7%; 95% CI = 2.4%- 5.6%) and *Haemoproteus* species + *Plasmodium* species + *Leucocytozoon* species (2.1%; 95% CI=1.2%-3.7%) infections.

Table 4 shows the prevalence of Avian Malaria Parasites encountered in domestic Rock Doves (*Columba livia domestica*) in Gombe State, Nigeria, based on study location and dove sex. Doves sampled and examined from live bird markets had higher prevalence rates of all avian malaria parasites than those sampled from households. Single infection of *Haemoproteus* species was more prevalent in doves sampled from live birds markets (7.9%) than in those sampled from households (6.5%), followed by *Plasmodium* species, which was also more prevalent in doves sampled from live birds markets (5.6%) than in those examined from households (4.6%). *Leucocytozoon* species was more prevalent in doves sampled from live birds markets (4.9%) than in those examined from households (2.1%), mixed infection of *Haemoproteus* spp. + *Plasmodium* spp. was more prevalent in doves sampled from live birds markets (2.8%) than those sampled from households (2.1%), *Leucocytozoon* spp. + *Plasmodium* spp. was more prevalent in doves sampled from live birds markets (2.5%) than those sampled from households (1.2%). Finally, *Haemoproteus* spp. + *Plasmodium* spp. + *Leucocytozoon* spp. was more prevalent in doves sampled from live birds markets (1.6%) than those sampled from households (0.5%). Furthermore, all avian malaria parasites identified were more prevalent in female doves than male doves, with the exception of *Plasmodium* and *Leucocytozoon* species, which had more single infections in male doves than female doves. Single *Haemoproteus* species infection was more prevalent in female (8.4%) than male (6.0%) doves, while *Plasmodium* species infection was more prevalent in male (5.6%) than female (4.6%) doves, and *Leucocytozoon* species infection was also more prevalent in male (3.7%) than female (3.3%) doves. Mixed infection of *Haemoproteus* spp. + *Plasmodium* spp. was more prevalent in female (2.5%) doves than male (1.9%) doves, mixed *Leucocytozoon* spp. + *Plasmodium* spp. was also more prevalent in female (2.1%) doves than male (1.6%) doves. Finally, *Haemoproteus* spp. + *Plasmodium* spp. + *Leucocytozoon* spp. was more prevalent in female (1.4%) doves than male (0.7%) doves (Figure 1).

Parameters	Information	Number of Doves examined	Avian Malaria Parasites Encountered						Total infected
			Haemoproteus spp. (%)	*Plasmodium* spp. (%)	*Leucocytozoon* spp. (%)	*Haemoproteus* spp. + *Plasmodium* spp. (%)	*Leucocytozoon* spp. + *Plasmodium* spp. (%)	*Haemoproteus* spp. + *Plasmodium* spp. + *Leucocytozoon* spp. (%)	
Study location	House holds	270	37 (6.5)	26 (4.6)	12 (2.1)	9 (1.6)	7 (1.2)	3 (0.5)	91 (33.7)
	Live birds market	300	45 (7.9)	32 (5.6)	28 (4.9)	16 (2.8)	14 (2.5)	9 (1.6)	147 (49.0)
	Overall	570	82 (14.4)	58 (10.2)	40 (7.0)	25 (4.4)	21 (3.7)	12 (2.1)	238 (41.8)
Sex	Male	285	34 (6.0)	32 (5.6)	21 (3.7)	11 (1.9)	9 (1.6)	4 (0.7)	111 (38.9)
	Female	285	48 (8.4)	26 (4.6)	19 (3.3)	14 (2.5)	12 (2.1)	8 (1.4)	127 (44.6)
	Overall	570	82 (14.4)	58 (10.2)	40 (7.0)	25 (4.4)	21 (3.7)	12 (2.1)	238 (41.8)

Table 4: Prevalence of Avian Malaria Parasites Encountered in Domestic Rock Doves (*Columba livia domestica*) based on Sex and Study Location in Gombe State, Nigeria.

Figure 1a & b: Showing domestication of Rock doves (*Columba livia domestica*) in Gombe State, Nigeria.

Discussion

Our research investigated the prevalence of avian haemosporidian parasites, which have been linked to avian malaria. The current study's findings have offered current information on the presence of avian malaria parasites in domesticated rock doves, indicating that apparently healthy doves could retain haemosporidian parasites without presenting clinical indications of illness. In this study, the overall prevalence rate of avian haemosporidian parasites was 41.8%, which is lower than 44.0% previously reported by Dey, et al. [27] from Mymensingh district in Bangladesh, as well as 78.0%, 80.0% and 64.0% reported by Dadi-Mamud, et al. Opara, et al. and Omonona, et al. [29-30] from Lapai, Niger State, Owerri, Imo State and Ibadan, Oyo Sate in Nigeria respectively. Variations in prevalence may be influenced by a range of factors, including sample size, type of study, ecological, geographic, bird population characteristics, and vector abundance.

The prevalence of avian haemosporidian parasite infections in domestic rock doves was higher in doves sampled from live bird markets (25.8%) compared to those sampled from households (16.0%), with a statistically significant (P <0.0001) association between the prevalence and the location of the sample collection. This finding could be linked to the fact that doves in live bird markets are mixed with a variety of avian species and are kept in cages without adequate arthropod screening nets, leaving them vulnerable to blood sucking arthropods, especially at night, which could infect them with any haemoparasites they may have, as opposed to those in homes, who are usually provided with proper housing. This finding supports the findings of Dunn, et al., Omonona, et al. and Emmenegger, et al. [30-32], who stated that feral birds with housing may be protected from vector exposure due to their enclosed surroundings, whereas those that are not properly housed may be more susceptible to flying dipteran vectors, resulting in higher prevalence in markets as compared to household reared doves. Moreover, birds in cages may be more vulnerable to infection due to overcrowding and cage tiredness which may lead to stress and immune-suppression. The current study also discovered that the rock doves sold in the market are more likely to have been captured directly from the wild, implying that they had been exposed to infection during migrating movements. This observation also supports the findings of Walther, et al. Emmenegger, et al., and Ciloglu, et al. [32-34], who found that migratory avian species, especially long-distance migrants, are expected to host a higher diversity of haemoparasites because they encounter parasites and their vectors in multiple ecosystems.

The findings of the present study revealed that the female (22.3%) doves had a higher prevalence of haemosporidian parasites than male (19.5%) doves, although there was no statistically significant association between sex of doves and the prevalent rates, which agrees with Senlik, et al. [35] who were unable to detect a significant difference in the infection rate of haemosporidian parasites in terms of host sex. This indicated that both sexes shared equal chances of getting infection in the availability and abundance of infected suitable vectors. However, Opara, et al. and Nath and Bhuiyan [29,36] have reported higher prevalence of haemosporidian parasites in female compared to male pigeons and have detected a significant association between sex and prevalence of haemoprotozoa infection. Our finding is contrary to the report of Dey, et al. [27] who have reported higher prevalence of haematozoa in male pigeons than the females. Female doves have a higher prevalence of haemosporidian parasites than male doves, which could be linked to stationary during the nestling stage, when female doves are sedentary throughout the egg incubation period, and this stationary time could have exposed them to a series of bites from infected vectors.

In the present study, three haemosporidian taxa, namely *Haemoproteus*, *Plasmodium*, and *Leucocytozoon* species, were found in the infected rock dove which supports the findings of Valkiûnas, Braga, et al. Ishtiaq, et al., Nath and Bhuiyan, Omonona, et al. and Mirzaei, et al. [19,30,36-39], who have also reported that these three genera of the Phylum Apicomplexa belonging to the families *Haemoproteidae*, *Plasmodiidae*, and *Leucocytozoidae*, respectively are the most frequently encountered haemosporidian parasites in avian from the family Columbiforms including doves. Among the detected haemosporidian, *Haemoproteus* was the most prevalent followed by *Plasmodium* and *Leucocytozoon* species which supports the findings of Opara, et al., Carlson, et al., Samani, et al., Nath and Bhuiyan, Heym, et al. and Schumm, et al. [29,36,40-43] who have also reported that *Haemoproteus* species is the most frequently encounter haemosporidian parasites in wild and domesticated bird species of the order Columbiformes. Previous studies has also shown that *Haemoproteus* species, specifically *H. columbae*, is the world representative cause of haemosporidian infection in rock doves (*Columba livia*), which includes domestic pigeons (*C. livia f. domestica*) [15,19]. There are at least five other *Haemoproteus* species in addition to *H. columbae*. Pigeons and doves (Columbiformes: *Columbidae*) are infected by the subgenus *Haemoproteus* Kruse, 1890, and are transmitted by hippoboscid flies [19]. *Haemoproteus* species has also been reported to occupy a large portion of erythrocytes; with its gametocytes partially encircling the erythrocyte nucleus, forming a halter-shaped appearance with little displacement of the host cell nucleus [44] thus, the detection of *Haemoproteus* species in domesticated rock pigeons in this study could indicate a serious health complication for the bird.

Our study found *Plasmodium* species as the second most prevalent haemosporidian parasite infection in the rock doves which in line with Nath and Bhuiyan [36], but contrast the findings of Carlson, et al. and Heym, et al. [40,42] who reported *Leucocytozoon* species as the second most frequent avian haemosporidian parasite in Columbiforms. Our finding might be associated with the abundance of mosquitoes and *Pseudolynchia* species which are the true vectors of *Plasmodium* and *Haemoproteus* in avian species as reported by Igbokwe, et al. [45] in the study area.

The finding of the present study reported for the first time the prevalence of *Leucocytozoon* species in domesticated rock doves. This haemosporidian parasite has previously been reported in feral pigeons which are widely distributed and their number is increasing, especially in urban areas as reported by Haag-Wackernagel and Moch and Nath, et al. [46,47]. Although the galliformes has been identified as the primary and true host of *Leucocytozoon*, other species of birds may be infected when bitten by an infected vector during blood sucking behaviors. Cross transmission from chickens may have resulted in the detection of *Leucocytozoon* specie in domesticated rock doves, as it was observed in this study that domesticated rock doves are reared in households with chickens and also kept in close proximity in live bird markets with chickens, potentially allowing for cross-transmission in the presence and abundance of blood sucking arthropods, which may transmit the parasite between these birds during blood meal. Pigeons had previously been found to carry *Leucocytozoon* species, suggesting that the haemosporidian parasite is not host specific or is adapting to a new host.

The prevalence rate of *Heamoproteus* species (14.4%) reported in rock doves from the present study is lower than 57.2% reported by Hussein and Abdelrahim [48] and 46.55% reported by Tietz-Marques, et al. [49] from Qena governorate and Lages-Santa Catarina, Brazil respectively, moreover lower than 76.5% and 24.5% reported in domestic pigeons (*Columba livia*) in Uganda and Bangladesh by Dranzoa and Nath and Bhuiyan [36] respectively as well as 24.0% reported in African mourning dove (*Streptopelia decipiens*) in Nigeria by Omonona, et al., Rosyadi, et al. [30,44] has reported a high prevalence of *H. columbae* (85.7%) infection in farmed domestic pigeons from Yogyakarta, Central Java, while Nebel, et al. [50] reported 72.7% in feral domestic pigeons in Cape Town, South Africa, and Hussein, et al. [48] reported 57.3% in Qena, Egypt. However, our finding was higher than 4.8% and 13.2% reported from northwestern Costa Rica and Bangladesh by Valkiunas, et al. and Elahi, et al. [17,51] respectively. These variations in prevalence rate of *Haemoproteus* species in doves and pigeons from the various studies might be due to habitat difference of doves, proximity to breeding area of vectors, geo-climatic condition, level of host resistance or susceptibility, season of sample collection and husbandry practices of pigeons and doves.

The prevalence of *Plasmodium* (10.2%) and *Leucocytozoon* (7.0%) discovered in rock dove in this study is lower than that reported by Akinpelu [52] in Red-eyed doves (11.1% and 10.0%, respectively) and Omonona, et al. [30] in African mourning doves (40.0% and 24.0% respectively) in Nigerian. However, Dadi-Mamud, et al. [28] reported 30.0% prevalence of *Plasmodium* and 3.0% prevalence of *Leucocytozoon* in pigeons in Nigeria. Various investigations in Nigeria have revealed that the susceptibility of different dove and pigeon species to these haemosporidian parasites varies. This could be due behavioural as well as physiological difference and some other intrinsic factors related to the immune status of different dove species which may make them more or less susceptible to parasitic infections. In the present study, sampling was limited to houses and live bird market places situated within the urban and sub-

urban areas. Other avian species, such as chickens and ducks, are more likely to have served as reservoirs because the parasites have been previously reported in these avian hosts in the study area, and the presence and abundance of different species of mosquitoes and black flies, the parasite's main vectors, allows for cross transmission of *Plasmodium* and *Leucocytozoon* species to domesticated doves raised in captivity. Moreover, Scaglione, et al. [53] states that the doves are not usually infected with *Leucocytozoon* species, even though, Chakarov, et al. [54] reported that the columbiformes are one of the main targets of ornithophilic blackflies which frequently transmit the parasite.

The total prevalence rates of mixed infection with *Haemoproteus* + *Plasmodium* in rock doves were 4.4%, according to the findings of this study, is lower than but comparable to 4.5% reported by Nath and Bhuiyan [36] in domestic pigeons in Bangladesh. In addition, the prevalence of mixed *Haemoproteus* + *Plasmodium* + *Leucocytozoon* (2.1%) detected in this study was also found to be lower than but comparable to 2.5% reported by Nath and Bhuiyan [36] in domestic pigeons in Bangladesh.

Conclusion and Recommendations

In conclusion, domesticated rock doves in the study area carry avian haemosporidian parasites belonging to the families *Haemoproteidae*, *Plasmodiidae*, and *Leucocytozoidae*, the most prevalent was *Haemoproteus* species, and detection of *Leucocytozoon* species in rock doves may signify a new host-parasite relationship. Prevalence of all avian haemosporidian parasites was higher in doves from live birds' markets, and higher in female doves. Future studies should be carried out to determine the possible role of these birds in the spread and/or persistence of these infections amongst other domesticated avian species in the study area. Further investigation using more sensitive detection techniques is necessary to characterize the true species and diversity of the haemosporidian parasites infecting rock doves.

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Conflict of Interest

The authors declare that they have no competing interests.

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