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Prevalence and diversity of intestinal parasites in household and temple pigeons (*Columba livia*) in central Nepal

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Abstract

Background: Intestinal infection, caused by various protozoans and helminths, represents one of the significant health concerns in pigeons around the world.

Objectives: The present study aimed to determine the diversity and prevalence of the intestinal parasites in pigeons found in Ratnanagar Municipality, Chitwan, in central Nepal.

Methods: The fresh faecal samples (n = 155) were non-invasively collected from different households and temples pigeons The individual samples were immediately preserved in the 2.5% potassium dichromate solution and transported to the research laboratory. Following direct wet mount and concentration methods, the samples were observed under a compound microscope.

Results: The results showed 87.1% prevalence rate with 16 parasite species that included 8 protozoan and 8 helminth faunae. The faecal samples of temple pigeons contained a higher prevalence rate with higher parasitic richness (95.6%; 16 species) than household pigeons (75.4%; 12 species). Mixed infection up to four different species was recorded in both types of sampling populations.

Conclusions: Pigeons harbour a greater prevalence and wider diversity of intestinal parasites and the parasitism varies based on the habitats. Proper management and effective deworming practices are recommended to control intestinal parasitic infection in these avian hosts.

KEYWORDS
Capillaria, *Caryospora*, *Cryptosporidium*, *Eimeria*, oocysts, temple pigeons

1 | INTRODUCTION

Columba livia, Taxonomic Serial Number 177071 (www.itis.gov), also referred to as the rock dove or rock pigeon, is a ubiquitous and abundant, monogamous avian species. Since prehistoric times, humans have adopted pigeons as symbols of gods and goddesses, peace, messengers, pets, food and religious sacrifice. Although they are the first known domesticated birds (Sossinka, 1982), most are wild and urban-dwellers and are considered vital species in the urban ecosystems (Capoccia et al., 2018). The IUCN Red List categorises them as Least Concerned species (BCN, 2018). In Nepal, they represent loved birds and are domesticated over time for their meat value or pets. However, the vast population of these birds is free-living. It can be found in and around various religious sites like temples, gumbas, monasteries

and urban cities all over the country. Besides the common rock dove, other pigeons like hill pigeon (*Columba rupestris*), snow pigeon (*Columba leuconota*), common wood pigeon (*Columba palumbus*), speckled wood pigeon (*Columba hodgsonii*) and ashy wood pigeon (*Columba pulchricollis*) are also reported in Nepal (BCN, 2018). Regarding feeding ecology, these birds exhibit a peculiar behaviour, and their selection of feed varies individually (Giraldeau & Lefebvre, 1985; Johnston & Janiga, 1995). They are mainly granivorous in feeding habits (Johnston & Janiga, 1995). However, they also consume seeds, domestic scraps, green leaves, berries, fruits, insects, snails, earthworms and small fish (Goodwin, 1975; Innis, 1989; Murton & Westwood, 1966; Spennemann & Watson, 2017).

Intestinal infection, caused by various protozoans and helminths, represents one of the significant health concerns in pigeons around the globe (Abdullahi et al., 2019; Bahrami et al., 2013; Harlin & Wade, 2009; Yousafzai et al., 2021). For instance, high morbidity and mortality followed by coccidiosis (Balicka-Ramisz & Pilarczyk, 2014; Balicka-Ramisz et al., 2021; Hunt & O'Grady, 1976; Rodriguez et al., 1997), capillariasis (Muthusami & Gopinath, 2017; Parsani et al., 2014; Pees, 2008; Qamar et al., 2017; Rodriguez et al., 1997), ascariasis (Abdel Rahman et al., 2019; Parsani et al., 2014; Radfar et al., 2012) and echinostomiasis (Ledwoń et al., 2016) in the pigeons have been reported from different landscapes. In addition, infection by parasites has been followed by a secondary infection in the pigeons, indicating its critical role in the consequences on health (Harlin & Wade, 2009). To date, very few studies regarding intestinal parasitism in these avian hosts have been conducted in Nepal. Postmortem examination of the captured pigeons performed during the 1920s–1940s reported cestodes like *Raillietina torquata*, *R. kantipura*, *R. nripendra* and *Nepalesiajoodhaii* sp. in Nepal (Meggitt, 1924; Sharma, 1943). Similarly, ascarid, *Capillaria* sp., *Echinostoma* sp., *Eimeria* sp., *Heterakis* sp., *Hymenolepis* sp., *Syngamus* sp. and *Tetrameres* sp. have recently been reported in the faecal samples of temple pigeons of Pokhara (Gurung, 2016) and Kathmandu (Jha, 2017). However, these studies were confined to only temple-inhabiting populations with a limited sample size that might not be adequate to explain the status of parasitism in these widely dispersed hosts. Thus, the current study aimed to compare and contrast the prevalence and diversity of intestinal parasites in the pigeons found in two different habitats/locations (households and temples) in central Nepal.

2 | MATERIALS AND METHODS

2.1 | Study area

The current study was conducted in Ratnanagar Municipality, situated in the eastern part of the Chitwan district, about 170 km from the capital city (Figure 1). The municipality is rich in fertile agricultural land,

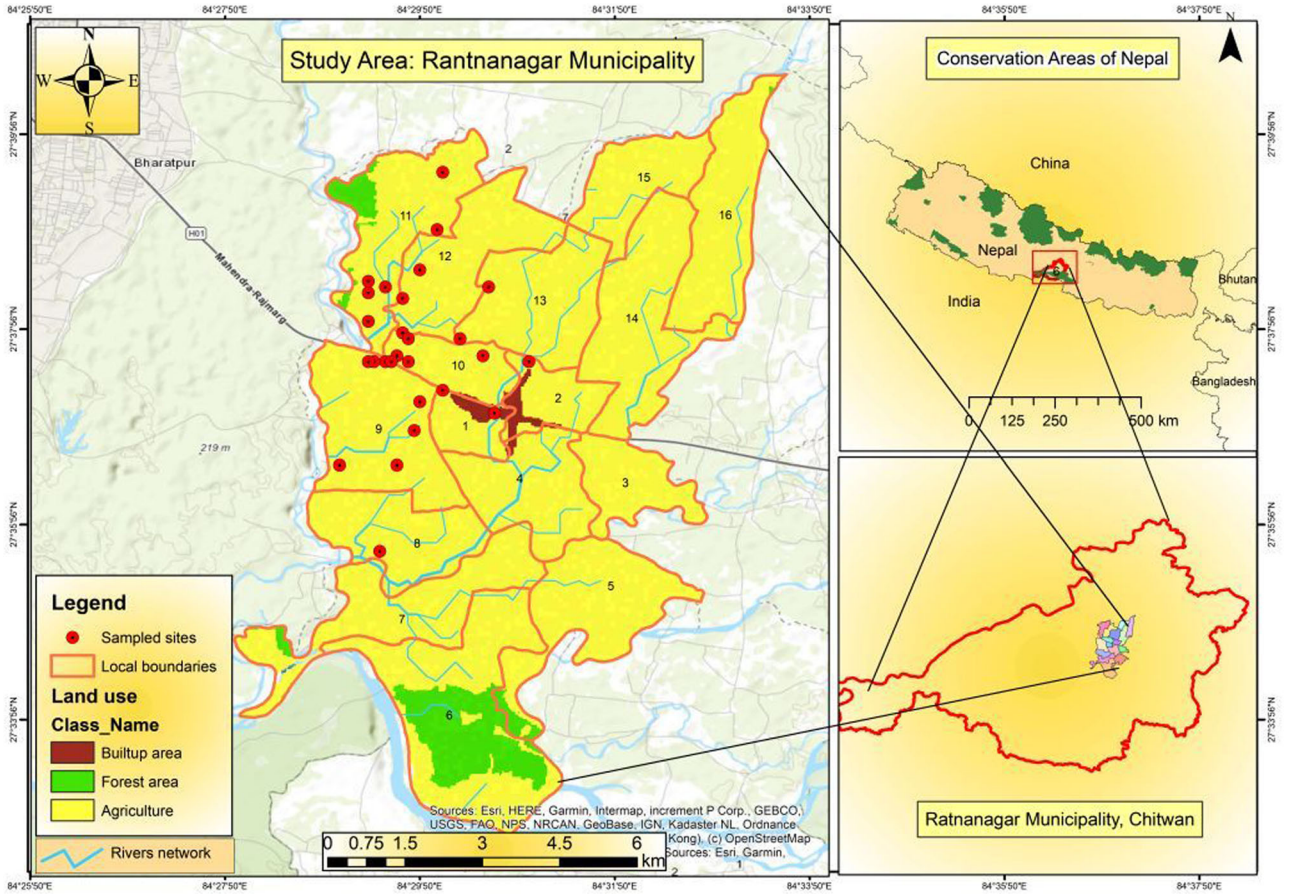
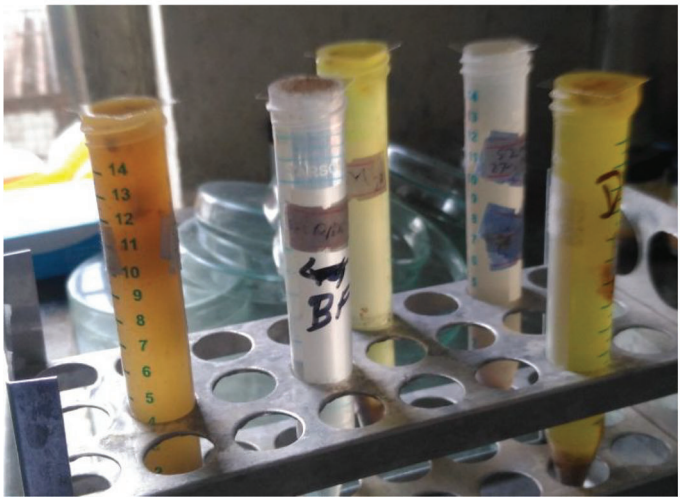


FIGURE 1 Map of the study area

FIGURE 2 Pigeons and their habitat. (a) Pigeons on indigenous lofts made up of soil inside the house (Khoyep or Daliya in *Tharu language*). (b) Traditional lofts of pigeons adjacent to house. (c) Pigeons in locally made water jar. (d) Temple pigeons feeding on the grains. (e) Household pigeons feeding on the grains

and significant occupation of the people includes agriculture, animal husbandry, poultry farming and fish farming. The area also includes the Barandaabhar forest, community forests and wetlands, supporting various wild animals and birds. Vegetation like Sal forest, riverine forest, mixed forest and grasslands are found in Ratnanagar Municipality. Few religious sites are Krishna Mandir (Tikauli), Dharma Dham (Jirauna), Gayatri Harihaar Mandir (Bakullahaar), Kalika Than (Panchakanya), Ram Mandir (Jayamangala), Ganesh Mandir (Ghegauli), Aatma Shanti Bouddha Gumba (Mangalpur) and others where pigeons are predominant. Feeding them with grains and ready-to-eat food products by religious persons, visitors and others is common. Besides, the local people also domesticate the pigeons at their homes for recreation and meat. In these contexts, the owners prepare traditional wooden lofts or indigenous soil-made lofts (Khoyep or Daliya in *Tharu* language) in their house. They also prepare local drums, water jars, or baskets for pigeon domestication and provide essential feeds to them (Figure 2).

(a) Acid-fast staining with malachite green (left two slides) and with carbol fuchsin (right ten slides)



(b) Processing of fecal samples through flotation technique

FIGURE 3 Laboratory processing of faecal samples. (a) Acid-fast staining with malachite green (left two slides) and with carbol fuchsin (right 10 slides). (b) Processing of faecal samples through flotation technique

2.2 | Faecal collection, preservation and transportation

From 10 September 2020 to 25 December 2020, 155 fresh faecal samples from household pigeons ($n = 65$) and temple pigeons ($n = 90$) were non-invasively collected. The pool samples from temple pigeons were collected overlaying a large clean plastic on the floor below each roosting site. The faecal matter rolling down the plastic was collected into the sterile vials with the help of a spatula. Care was taken to avoid the contamination of the faecal samples with different faeces of other birds in the temples. In contrast, faecal droppings from each household pigeon were collected from the nests of 21 households. All the faecal samples were kept in a 10 ml screw-capped sterile vial and then preserved in 2.5% potassium dichromate solution w/v at 4°C. Finally, the collected faecal droppings were transported to the Animal Research Laboratory (Nepal Academy of Science and Technology, Lalitpur) for processing and examinations.

2.3 | Processing, examination and identification

The samples were processed to direct wet mount, formalin ethyl acetate (FEA) sedimentation, saturated salt flotation (45% w/v of NaCl) and acid-fast techniques as previously explained (Figure 3) (Adhikari & Ghimire, 2021; Adhikari et al., 2020; Adhikari et al., 2021b; Adhikari et al., 2021c; Aryal et al., 2021; Adhikari et al., 2021a; Ghimire & Bhattarai, 2019). For direct wet mount, a single drop of iodine solution was put in the faecal sample and it was directly observed under the microscope. For formalin ethyl acetate sedimentation, almost 2 gm of the faecal sample was mixed with normal saline (0.9% NaCl) in a 15 ml conical centrifuge tube and centrifuged at 1200 rpm for 5 min. Following discarding the supernatant, 10 ml 10% formalin and 4 ml ethyl acetate were added to the sediment and recentrifuged (1200 rpm for 5 min). Finally, the upper supernatant layer and middle debris layer were discarded and a single drop of the sediment was transferred to the glass slide. A drop of iodine was applied to the sediment and observed under

the microscope. For flotation technique, the sediment was put in the concentrated common salt (NaCl, 45% w/v) and centrifuged (1200 rpm for 5 min). Further, concentrated salt solution was added drop by drop to completely fill the tube and a coverslip was kept at its mouth in such a way that it just touched the flotation media. After 10 min, the coverslip was removed and kept on the glass slide for microscopic observation. Similarly, for acid fast staining, the sediments obtained from formalin ethyl acetate sedimentation were used. A thin smear of the sediments was prepared following drying at room temperature. The smear was initially fixed in absolute methanol for 2 min then counterstained with carbol fuchsin for 15 min and de-stained with acid alcohol. The smear was further stained with malachite green for a minute and gently washed with distilled water. Finally, the dried smear was observed under microscope at 1000× with immersion oil. Microscopic examination was carried out under a light microscope (B-383PLi, OPTIKA) at varying magnifications, that is, 100×, 400× and 1000×, and photomicrographs of different parasite stages like trophozoites, cysts, oocysts, eggs and larvae were taken by a camera (SXView 2.2.0.172 Beta) attached to the microscope. Further, using ImageJ 1.51k (National Institute of Health) software, the size of the photographed parasites was measured, and their identification was performed based on the literature (Matsubara et al., 2017; Ortúzar-Ferreira et al., 2020; Soulsby, 2012; Santana-Sánchez et al., 2015).

2.4 | Data analysis

Data were expressed in tables in Microsoft Word & Excel 2007. The percentage prevalence was calculated, dividing total positive samples by total number of samples and multiplying it by 100. The sizes of coccidian oocysts like *Eimeria* spp., *Isospora* sp. and *Caryospora* sp. were analysed using length (*l*) as well as breadth (*b*) (minimum, maximum and average) and *l*/*b* ratio based on previously published literature (Matsubara et al., 2017; Ortúzar-Ferreira et al., 2020; Santana-Sánchez et al., 2015) (Supplementary Information 1).

$$\text{Prevalence (\%)} = \frac{\text{No. of positive samples}}{\text{No. of total samples}} \times 100.$$

3 | RESULTS

In the current study, the prevalence of the parasites was 87.1% (135 out of 155 faecal samples) in the studied pigeon population. It was important that there were 16 parasites with the following prevalence rates: *Eimeria columbae* (46.5%), *Capillaria columbae* (29.7%), *Eimeria* columbarum (23.2%), *Ascaridia* sp. (22.6%), *Entamoeba* sp. (14.2%), *Eimeria labbeana* (10.3%), *Echinostoma* sp. (8.5%), *Heterophyes* sp. (7.7%), *Eimeria kapotei* (7.7%), *Isospora* sp. (7.1%), *Heterakis* sp. (7.1%), *Capillaria annulata* (5.8%), Strongyle (5.2%), *Caryospora* sp. (3.9%), *Cryptosporidium* sp. (3.9%) and *Hymenolepis* sp. (1.9%) (Figure 4). The prevalence of protozoa was slightly higher than the helminths (78.7% vs. 69.7%); however, the species diversity remained the same (eight species in each parasitic group) (Table 1).

The diversity and prevalence of intestinal parasites between the household and temple pigeons were compared. Temple pigeons had a higher prevalence rate than household pigeons (95.6% vs. 75.4%). Similar results were found regarding the diversity of the parasites (16 species vs. 12 species). Both protozoa (90% vs. 63.1%) and helminths (74.4% vs. 63.1%) were found at higher rates of prevalence in temple pigeons compared to those in household pigeons (Table 1).

Finally, the concurrency of parasitic infection was evaluated. Overall, the prevalence was higher for the samples that contained two species of intestinal parasites. Both types of pigeons had higher numbers of samples positive with mixed species (60% vs. 85.6%) compared to those with single species (15.4% vs. 10%) (Table 1). Similarly, the concurrency of *Eimeria* spp. (any of *E*. columbae/*E. columbarum*/*E. labbeana*/*E. kapotei*) and *Capillaria* spp. (any of *C. columbae* and or *C. annulata*) was recorded in 38 (24.5%) faecal samples with a maximum triplet infection (Supplementary Information 2).

4 | DISCUSSION

Firstly, the prevalence of intestinal parasites in the pigeons was analysed in the current study. The prevalence rate (87.1%) was lower than the findings from previous studies among feral pigeons from Nepal (90.83%; $n = 120$) (Jha, 2017), Bangladesh (100%; $n = 60$) (Begum & Sehrin, 2013), Poland (100%; $n = 90$) (Balicka-Ramisz et al., 2021) and India (91%; $n = 78$) (Parsani et al., 2014) and higher than the findings from Iran (79.2%; $n = 250$) (Bahrami et al., 2013), Brazil (74.14%; $n = 58$) (Tietz Marques et al., 2007), India (72.7%; $n = 132$) (Sivajothi & Sudhakara, 2015), Pakistan (73.33%; $n = 210$) (Baber et al., 2020) and (60%, $n = 30$) (Yousafzai et al., 2021), Bangladesh (70.76%; $n = 65$) (Islam et al., 2017), Nepal (69.16%; $n = 120$) (Gurung, 2016), Turkey (59.6%; $n = 136$) (Sari et al., 2008) and Libya (56%; $n = 100$) (Alkharigy et al., 2018). The variation in these results might be attributed to the sampling techniques, the sampling size, the examination methods, the detected parasites and the ecology of sampling geographies. The study from Bangladesh involved histopathologic findings that contained 100% parasites (Begum & Sehrin, 2013). In the current study, faecal sampling was carried out, and microscopic techniques that might be less sensitive were used. However, both direct wet mount and concentrated methods were employed in each sample, ensuring a considerable number of positive cases and species richness in the current study.

In another context, the prevalence and diversity of the reported intestinal parasites were compared between the household and temple pigeons. The current study suggested that variation in the parasites existed in different pigeon populations; however, it is difficult to point out the underlying causes. It was observed that the population of pigeons in all temples was higher than in any of the domesticated farms. First, host interactions in the temple scenario are usual and may result in parasitic transmission. Second, even though pigeons are natural scavengers, with the easy availability of the feed, they may remain within their home range (Ryan, 2011), which is more likely for the household pigeons.

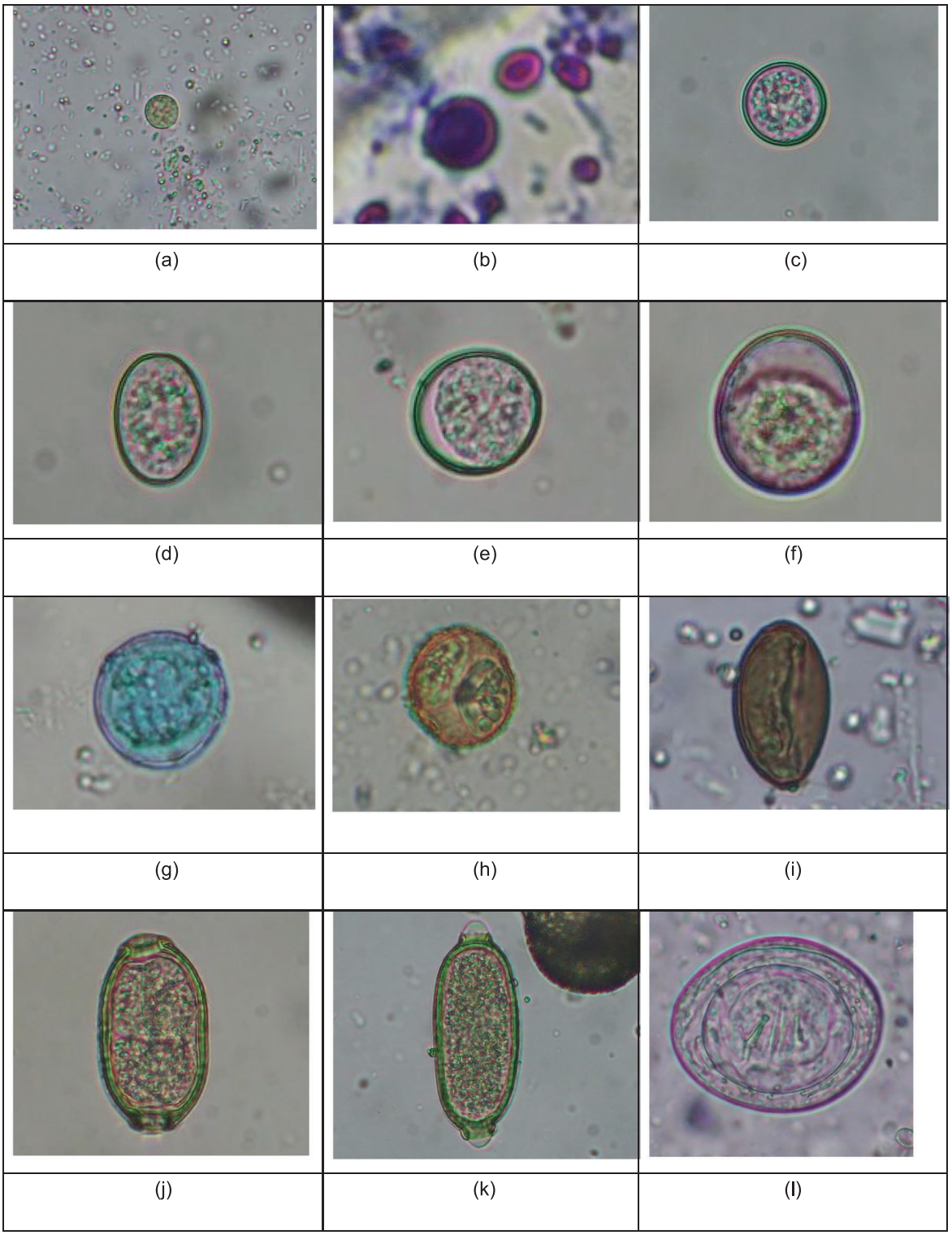


FIGURE 4 Intestinal parasites identified in the pigeons. (a) Cyst of *Entamoeba* sp. (10 × 10 μm), 400× after sedimentation at Gram's iodine. (b) Oocyst of *Cryptosporidium* sp. (5 × 4 μm), 1000×, after acid-fast staining. (c) Oocyst of *Eimeria columbae* (16 × 15 μm), 400× after flotation. (d) Oocyst of *Eimeria labbeana* (21 × 16 μm), 400× after flotation. (e) Oocyst of *E. columbarum* (20 × 18 μm), 400× after flotation. (f) Oocyst of *E. kapotei* (26 × 23 μm), 400× after flotation. (g) Oocyst of *Caryospora* sp. (25 × 24 μm), 400× after sedimentation. (h) Oocyst of *Isospora* sp. (27 × 25 μm), 400× after direct wet mount at Gram's iodine. (i) Egg of *Heterophyes* sp. (30 × 17 μm), 400× after sedimentation at Gram's iodine. (j) Egg of *Capillaria columbae* (48 × 27 μm), 400× after flotation. (k) Egg of *Capillaria annulata* (63 × 24 μm), 400× after flotation. (l) Egg of *Hymenolepis* sp. (58 × 36 μm), 400× after sedimentation at Gram's iodine. (m) Egg of *Ascaridia* sp. (81 × 47 μm), 400× after sedimentation at methylene blue. (n) Egg of Strongyle (90 × 54 μm), 400× after sedimentation at methylene blue. (o) Egg of *Echinostoma* sp. (98 × 58 μm), 400× after sedimentation at methylene blue. (p) Egg of *Heterakis* sp. (58 × 43 μm), 400× after direct wet mount at 2.5% potassium dichromate solution

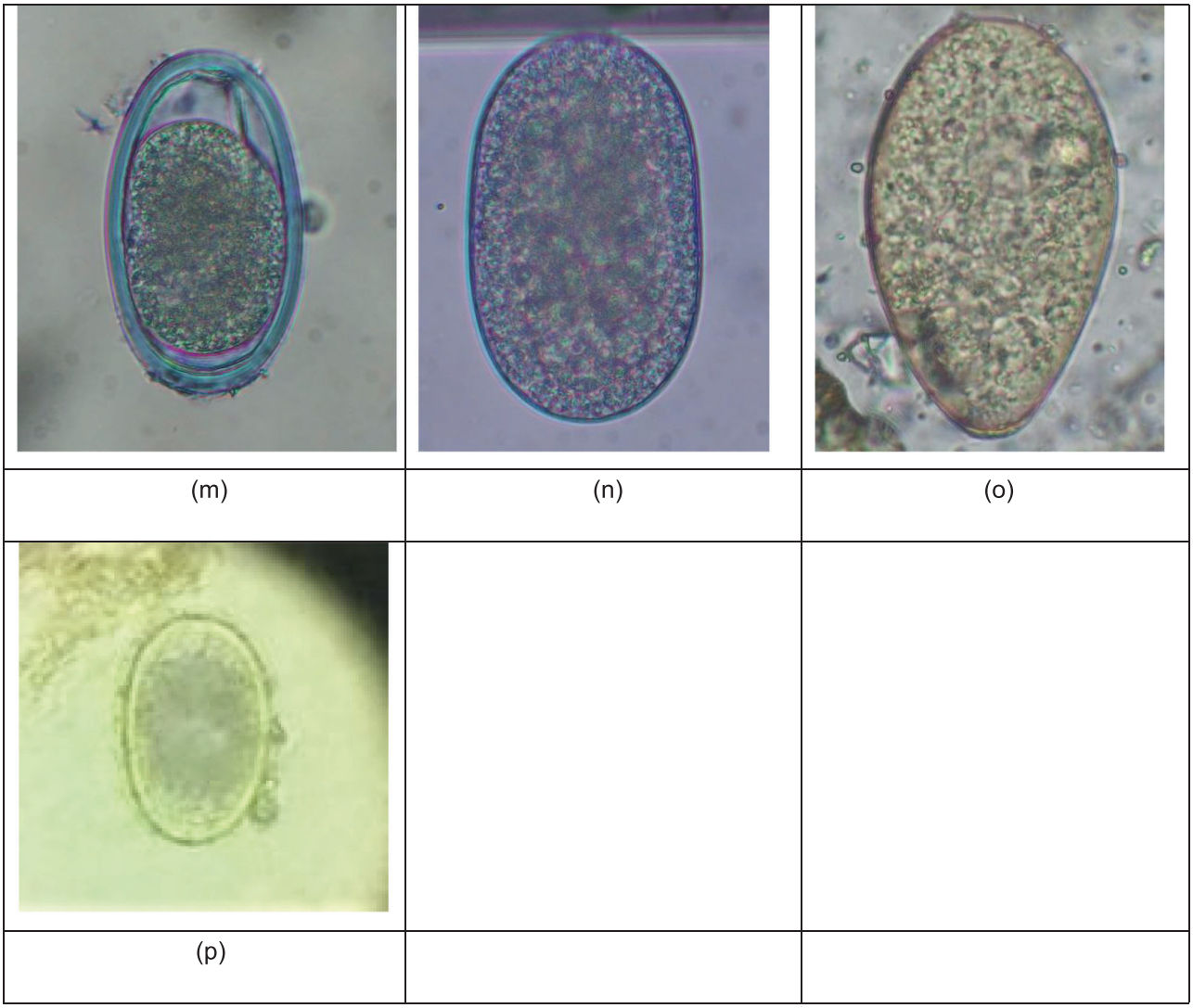


FIGURE 4 Continued

In contrast, with scarce meal nearby, pigeons can also travel for a longer distance, far away from their roosts (Ryan, 2011), which correlated with the current situation for the temple pigeons. Due to the first Coronavirus disease 2019 (COVID-19) lockdown in the country, temples had been closed for religious people and visitors, and the pigeons were facing a scarcity of feed. In this context, the pigeons travelled for a longer distance and consumed whatever food was available. Thus, the scavenging behaviour enhances exposure to the diverse environmental condition, including contact with other avian species, which consequently increases the various parasites' acquisition.

Interestingly, seven species of coccidia were detected in the pigeons, and the prevalence and diversity were higher in those of temple populations. *E. columbae* (46.5%) showed a higher prevalence rate similar to reported in Nigeria (Joseph et al., 2017). Further, the prevalence rate of *E. columbarum* (23.2%) and *E. labbeana* (10.3%) was comparatively lower than those reported from India (Saikia et al., 2017) and Turkey (Sari et al., 2008); however, the occurrence of *E. kapotei* (7.7%) was almost similar to that reported from China (Huang, 2018). It indicates that eimerian parasites are dominant in pigeon-dwelling regions. Further, it was also discussed that, among the various species (about nine) of eimerian parasites in pigeons, three species mainly; *E. columbae*, *E. columbarum* and *E. labbeana* are pathogenic in these hosts (Balicka-Ramisz & Pilarczyk, 2014). Another coccidian *Isospora* sp. was significantly lower (7.7%) than those reported from India (70%) (Singh & Mohilal, 2017) and Turkey (18.4%) (Sari et al., 2008) and higher than that reported from India (0.22%) (Saikia et al., 2017). Interestingly, the presence of *Caryospora* sp. in the temple pigeons was uniquely reported in this study. This coccidian is common in raptors (McAllister et al., 2013; Santana-Sánchez et al., 2015); thus, cross-transmission between pigeons and raptors may occur due to their shared overlapping niches. However, further epidemiological studies should warrant it. To date, oocysts of *Cryptosporidium hominis*, *C. parvum*, *C. baileyi* and *C. meleagridis* have been detected in pigeons (Abreu-Acosta et al., 2009; Koompapong et al., 2014; Li et al., 2015; Oliveira et al., 2017). The prevalence of *Cryptosporidium* sp. (3.9%) in the current report was similar to that of Brazil (4%) (Oliveira et al., 2017), slightly lower than that of Spain (5.9%)

TABLE 1 Prevalence (%) and concurrency (%) of intestinal parasites among pigeons ($N = 155$)

Species	Household pigeons ($n1 = 65$) (%)	Temple pigeons ($n2 = 90$) (%)	Overall ($N = 155$) (%)
Protozoa			
Eimeria columbae	24 (36.9%)	48 (53.3%)	72 (46.5%)
Eimeria columbarum	17 (26.2%)	19 (21.1%)	36 (23.2%)
Entamoeba sp.	6 (9.2%)	16 (17.8%)	22 (14.2%)
Eimeria labbeana	0 (0%)	16 (17.8%)	16 (10.3%)
Eimeria kapotei	0 (0%)	12 (13.3%)	12 (7.7%)
Isospora sp.	3 (4.6%)	8 (8.9%)	11 (7.1%)
Caryospora sp.	0 (0%)	6 (6.7%)	6 (3.9%)
Cryptosporidium sp.	4 (6.2%)	1 (1.1%)	5 (3.9%)
Total	**41 (63.1%)**	**81 (90%)**	**122 (78.7%)**
Helminths			
Capillaria columbae	20 (30.8%)	26 (28.9%)	46 (29.7%)
Ascaridia sp.	15 (23.1%)	20 (22.2%)	35 (22.6%)
Echinostoma sp.	8 (12.3%)	5 (5.6%)	13 (8.5%)
Heterophyes sp.	2 (3.1%)	10 (11.1%)	12 (7.7%)
Heterakis sp.	3 (4.6%)	8 (8.9%)	11 (7.1%)
Capillaria annulata	2 (3.1%)	7 (7.8%)	9 (5.8%)
Strongyle	1 (1.5%)	7 (7.8%)	8 (5.2%)
Hymenolepis sp.	0 (0%)	3 (3.3%)	3 (1.9%)
Total	**41 (63.1%)**	**67 (74.4%)**	**108 (69.7%)**
Grand total	**49 (75.4%)**	**86 (95.6%)**	**135 (87.1%)**
Concurrency			
Single	10 (15.4%)	9 (10%)	19 (12.3%)
Double	23 (35.4%)	44 (48.9%)	67 (43.2%)
Triple	14 (21.5%)	17 (18.9%)	31 (20%)
Quadruple	2 (3.1%)	16 (17.8%)	18 (11.6%)

(Abreu-Acosta et al., 2009), and higher than those of Iran (2.94%) (Radfar et al., 2012) and China (0.82%) (Li et al., 2015). As these coccidia are zoonotic, further epidemiologic and molecular studies should include the faecal samples of humans and pigeons.

Entamoeba sp. is expected in the avian population (de Almeida Brito et al., 2017; Marietto-Goncalves et al., 2008); however, this species was first detected in the pigeons from Nepal in the current study. Its detection indicates the possibility of ingesting cyst-contaminated water, food or soil or accidental feeding on mechanical vectors like flies and beetles by pigeons (Graczyk et al., 2005).

In this study, *Capillaria* spp. dominated all the helminths with the detection of their two species (*C. columbae*: 29.7% and *C. annulata*: 5.8%). Similar to our results, these threadworms were also dominantly reported from pigeons around the various geographies; Nepal (31.67%) (Gurung, 2016), India (17.4%) (Sivajothi & Sudhakara, 2015), Pakistan (51%–73.33%) (Baber et al., 2020; Qamar et al., 2017) and Turkey (19.9%) (Sari et al., 2008). Similarly, *Ascaridia* sp. had a prevalence rate of 22.6% that was similar to the report from Nepal (Gurung, 2016) and Libya (Alkharigy et al., 2018) and contrasting to the information from India (33.3%) (Sivajothi & Sudhakara, 2015) and Bangladesh (30%) (Islam et al., 2017; Roy & Rahman, 2017). Similarly, *Heterakis* sp. was present in 7.1% of the faecal samples in the present study. This finding was higher than that reported from Turkey (3.7%) (Sari et al., 2008) but lower than the previous reports from Libya (18%) (Alkharigy et al., 2018) and Nepal (19.17%) (Jha, 2017). Even though these nematodes are considered non-pathogenic, their presence might warrant caution because these worms are critical vectors of Histomonas meleagridis that lead to blackhead diseases in poultry and game birds (McDougald, 2005)

There were only two trematodes, *Echinostoma* sp. and *Heterophyes* sp., in the pigeons. The prevalence rate of *Echinostoma* sp. (8.5%) was slightly higher than that reported from Nepal (7.5%) (Gurung, 2016) and lower than that reported from Bangladesh (15%) (Begum & Sehrin, 2013). Interestingly, 7.7% of the faecal samples were positive for *Heterophyes* sp. Even though the presence of this trematode is a unique finding, the in vivo development of *Heterophyes* sp., along with another homologous heterophyoid fluke (*Pygidiopsis genata*) had already been confirmed in the pigeons (Mahdy et al., 2020). Both of these species are transmitted by consuming intermediate hosts like snails and fish (Chai & Jung, 2017; Ledwoń et al., 2016), indicating a need for further study on the intestinal parasitic species concerning feeding ecology or diet analysis of the pigeons.

The only cestode and the least prevalent species of intestinal parasite was *Hymenolepis* sp., and it was reported only in three faecal samples of the temple pigeons. Its prevalence rate (1.9%) was much lower than that reported from Bangladesh (63.33%) (Begum & Sehrin, 2013) and marginally lower than that previously reported from Nepal (3.3%) (Gurung, 2016). Its positive case might be due to the ingestion of the intermediate hosts like grain beetles, fleas, or other insects carrying infective stages, which are the risks of *Hymenolepis* sp. infection in definitive hosts (Thompson, 2015).

Finally, considering the concurrency of parasitic infection, most of the pigeons (74.8%) were infected with multiple species of parasites. In nature, multiple parasitic infections in the host is a rule (Hoarau et al., 2020) that is basically analysed with the outcome of the competing parasites either within the same species or others, resulting in a positive, negative or neutral interaction (Bordes & Morand, 2011). Regarding a negative interaction, multiple infections by *Eimeria* spp. and *Capillaria* spp. led to the pathologic conditions in pigeons (Ramesh et al., 2018). Therefore, considering our coinfection results of these two parasites, the current studied pigeon population might have poor intestinal health. It indicates that the presence of multiple parasites increases the risk of deteriorated intestinal health in the pigeons. However, the current study lacks the pathological findings; thus, a detailed histopathological survey should be conducted further.

5 | CONCLUSIONS

The present study displayed the prevalence and diversity of intestinal parasites in household and temple pigeons. It highlighted that temple

pigeons were dominant with diverse species of parasites. These findings also suggest that the intestinal parasites can be health determinant factors for pigeon species. The study can serve as baseline data for veterinarians and parasitologists in designing a deworming strategy for the avian population and in farm management to minimise the risk of parasitosis.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

ETHICS APPROVAL

The authors declare that the study was conducted on naturally infected pigeons present in households and temples in Ratnanagar, Chitwan. No experimental infection was established during this research work. The required permission for the fieldwork and collection of the faecal samples was issued by Ratnanagar Municipality and Municipality Veterinary Services, Ratnanagar (Permission number: 7264 /2077).

AUTHOR CONTRIBUTIONS

RBA and TRG planned the work. RBA worked in the field and laboratory and wrote the first draft of the manuscript. MAD and TRG analysed the data. PBA prepared the Arc GIs map of the study area and reviewed the manuscript. All authors read the manuscript and finalised it.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in the supplementary material of this article.

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