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Parasitic Prevalence in Wild and Captive Birds Along an Altitudinal Gradient in Punjab, Pakistan

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ABSTRACT

Haemosporidians are intracellular avian parasites and have serious impact on captive and wild birds worldwide. These avian parasites cause serious infections which ultimately cause decline in population of both wild and captive birds even can cause their extinction. Environmental changes especially variation in temperature and altitudinal gradient have great impact on distribution of ectoparasites and endoparasites in both captive and wild birds worldwide. These parasites affect bird population badly and cause massive mortality in captive birds. In the current study, conducted from April 2021 to December 2021, we investigated prevalence of seventeen endoparasites and ectoparasites, in eight captive and wild birds along altitudinal gradient. We collected ectoparasites externally using forceps and endoparasites by blood samples of total 960 sampled birds and examined them under microscope. Total 136 birds found having 37.8% parasitic prevalence. *Raillietina echinobothrida*, a Cestode parasite, showed maximum 78% prevalence recorded in Turkeys sampled from Khanewal (73%) situated at 128m from sea level, 68% at 39°C in July 2021. *Histomonas meleagridis*, a protozoan parasite, showed minimum 8% in wild pigeon sampled from Rawalpindi situated at 508m above sea level, 6% at 20°C in December 2021. Results concluded that raise in temperature also increases the parasitic prevalence but it is decreased with the increase in elevation above sea level. It was concluded that three Haemoparasite species, six nematodes species, one cestode species, three protozoan species and two trematodes species of parasites were observed and identified from fecal and blood samples.

INTRODUCTION

A large number of bird species, numbering over 10,000, migrate between different countries and continents (Barrowclough *et al*., 2016; Benskin *et al*., 2009). Wild birds are known to be a significant source of various diseases which can be transmitted to both humans and animals, including parasitic, mycotic, viral, fungal, and bacterial diseases (Mihaela and Marina, 2014). These diseases are also spread to aquatic environments (Zhao *et al*., 2017; Hird *et al*., 2015) and can lead to multiple abnormalities in infected humans, or cause the infected to become carriers (Lagerstrom and Hadly, 2021). Wild birds transmit these diseases to animals and humans beyond local outbreaks (Rahman *et al*., 2020). Pakistan has great variety of avian species and is blessed with more than 650 bird species, found in three zone from zoogeographical point of view such as Ethiopian, Oriental and Palearctic. Such distribution makes Pakistani avian unique (Chagas *et al*., 2017). Birds have worldwide distribution and they are considered to be 150 million years old vertebrates. Their diversity reveals ecological and morphological relationships and have maximum density of population in the Neotropics (Jenkins *et al*., 2013).

Raise in global temperature also increases geographical distribution of parasitic prevalence along

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altitude and latitude (Yousafzai *et al*., 2021). This increase in parasitic prevalence also increases infectious diseases which ultimately cause threatened species and extinction of species (Faraj and Al-Amery, 2020). Variation in temperature and rainfall affect parasitic prevalence and distribution worldwide (Zamora-Vilchis *et al*., 2012).

Coproparasitological surveys helped in analysis of parasitic prevalence of exotic and indigenous birds and animals until 1970s (Bunbury *et al*., 2008; Patra *et al*., 2021). Today, this types of study is common worldwide due to increase in diversity of birds and their vast geographical distribution. These birds carry variety of parasites and are a great threat for health of other animals and humans with which they interact (Dashe and Berhanu, 2020). Parasitic infections which have great significance in avian diseases, can affect health of wild birds even they can cause death of their host birds (Reed *et al*., 2003). In addition, endoparasites greatly affect birds health and cause serious infections especially in developing countries. Even these parasites can cause decline or extinction of their host population (Thompson, 2013). Therefore, parasitic infections are considered one of the major factors which cause a considerable loss to wildlife worldwide (Meister *et al*., 2023).

Wild and captive birds are usually infected by wide variety of parasites such as nematodes, cestodes, protozoans, trematodes and acanthocephalans. Such birds affect health of animals and humans when they interact with them (Otegbade and Morenikeji, 2014; Girisgin *et al*., 2017; Hasan *et al*., 2018). Moreover, captive birds such as cage birds are always under high risk of intestinal parasitic infections especially protozoan and nematodes infections which are more common. Parasitic prevalence in captive birds is directly proportional to sanitary conditions of cages of these birds and affect high density populations easily (Hasan *et al*., 2018). Consistence exposure of parasites cause serious issues such stress, prolonged confined housing, illness, injuries and adaptations to infected environment. Concentration of parasite eggs depends upon sanitary conditions and housing environment. Birds can take get exposure to these parasite eggs through contaminated water, food, litter and insects with which they interact (Niranjan *et al*., 2020). Commercial farmers consider captive facilities much better because higher density of birds increases transmission of parasitic prevalence in birds (Krystianiak *et al*., 2007).

Parasitic infections caused by major parasites infect both wild and captive birds and cause significant impact on bird physiology and metabolism (Niranjan *et al*., 2020). Parasitic infections of intestines in captive and wild birds caused by helminths and protozoans have significant health concern worldwide (Adhikari *et al*., 2022; Yousafzai *et al*., 2021). Haemosporida are major blood parasites that are transmitted through vectors and affect their hosts seriously (Kleinschmidt *et al*., 2022). *Raillietina echinobothrida* is of the most significant pathogenic tapeworms worldwide and important member of the class Cestoda that causes nodular tapeworm disease in a variety of birds (Al-Marsomy and Al-Hamadaani, 2016) and causes distinct intestinal nodules in their hosts (Kumar *et al*., 2019). *Ascaridia* species are the most common nematode parasites of birds. They include *Ascaridia galli* and *Ascaridia columbae* (Abdel Rahman *et al*., 2019). *A. galli* is a pathogenic roundworm of Nematoda phylum (Tarbiat, 2018) and is another common parasite of birds that causes a common worldwide disease, Ascaridiasis (Faraj and Al-Amery, 2020) in important bird species such as pigeons, turkey, duck, goose, and guinea fowl which is characterized by reduction in growth rate and egg production in birds ultimately causes major economic losses for poultry farmers (Al-Quraishi *et al*., 2020). *A. galli* is highly prevalent nematode that is common health problem (Yousaf *et al*., 2019). *Ascaridia* infection causes reduction in body and health condition, increase in feed conversion ratio, and depression of immune system leading to increase concurrent diseases in host bird species (Wongrak *et al*., 2014).

Parasites cause different diseases in both wild and captive birds such as flu, malaria and ornithosis. Examples of ectoparasites of birds are mites, flies and ticks while endoparasites are protozoans, nematodes, cestodes, acanthocephalans and trematodes (Yadav *et al*., 2021). Parasitic prevalence in birds depends upon different factors such as bird species, sex, age and ecological conditions (Valkiunas *et al*., 2005). Even there is significant difference in prevalence of blood parasites of closely related bird species. Juvenile birds are under greater risk of parasitic prevalence in comparison with adult birds. These blood parasities have affected reproductive rates, plumage, survival, coloration and community structure of their hosts (Fokidis *et al*., 2008). Prevalence, geographic distribution and host range expansion of pathogenic infections under the influence of varying landscapes and changing climate, are being studied for disease ecology (Parratt *et al*., 2016; Stephens *et al*., 2016). Yet impact of these pathogens on humans and other animals is not fully controlled (Stephens *et al*., 2016).

Prevalence of parasites affects conservation and health of captive and wildlife bird species while captive birds are at the risk of parasites attack more than wild birds (Ombugadu *et al*., 2018). Therefore, prevalence and identification of parasites both in wild and captive birds is very important to understand diagnosis, transmission, epizootiology, control and their pathogenicity. Parasitic prevalence is associated with subclinical infections which cause pathogenicity due to stress conditions. Regular examination of parasitic infections after appearance of specific symptoms are very important to control pathogenic prevalence (Papini *et al*., 2012). Birds kept in captivity are more susceptible to parasitic attack which affects their reproduction, growth and survival. This can lead towards extinction of bird species and can be obstacle in their conservation especially for those, at risk of being endangered (Adhikari *et al*., 2022; Mirza and Wasiq, 2007). Similarly, prevalence of blood parasites varies even among closely related bird species. Higher level of prevalence is documented in juvenile birds than adults. Community structure of their hosts, coloration, plumage, reproductive rates and survival of birds are all affected by blood parasites (Fokidis *et al*., 2008).

Vector borne haemosporidians causes infections in birds, reptiles, amphibians and mammals of the whole world, such as *Plasmodium*, transmitted by mosquitoes, spread malaria in birds. Similarly, Ceratopogonidae (midges) transmit haemoproteus and Simuliidae (black flies) cause transmission of leucocytozoon (Valkiunas *et al*., 2005). Such parasites, haemosporidian, affect health status and fitness of wide variety of bird species worldwide and cause massive mortality in their targeted bird species (Palinauskas *et al*., 2008; Dimitrov *et al*., 2015). Even some blood ectoparasites, such as *Plasmodium*, can cause extinction of native bird population at large scale (Atkinson and LaPointe, 2009) and other infectious effects such as less immunity and reduced reproductive ability (LaPointe *et al*., 2012; Asghar *et al*., 2015).

The aim of this study was to record parasitic prevalence of seventeen ectoparasites and endoparasites (blood parasites) in selected eight captive and wild avian species with respect to variation in temperature and elevation levels sampled from eight districts.

MATERIALS AND METHODS

Study site and sampling

Total 480 captive birds such as peafowls (*Pavo cristatus*), ring-necked pheasants (*Phasianus colchicus*), turkeys (*Meleagris gallopavo*), pigeons (*Columba livia domestica*), and wild birds such as sparrows (*Passer domesticus*), crows (*Corvus splendens*), mynas (*Acridotheres tristis*) and wild pigeons (*Columba livia*) were collected from district Bahawalpur, Khanewal, Okara, Kasur, Lahore, Sargodha, Chakwal and Rawalpindi.

Ectoparasitic collection

One hundred and twenty mature birds (male and female) of each species i.e. captive bird species viz. *P. cristatus*, *P. colchicus*, *M. gallopavo* and *C. livia domestica* and wild birds i.e. *P. domesticus*, *C. splendens*, *A. tristis* and *C. livia*, were visually inspected and their whole body were fully examined. The parasites were collected using forceps and observed under stereo microscope and identified (Fokidis *et al*., 2008).

Fecal matter sampling

Fresh fecal droppings of selected experimental birds were collected and brought to the Department of Wildlife and Ecology, University of Veterinary and Animal Science, Lahore (31.044398, 73.874542) for corpological examination.

Ectoparasitic analysis

The samples were examined by direct fecal smear method, simple floatation and sedimentation techniques to detect parasitic oocytes and/or eggs. Later on, quantitative fecal sample examination, in term of oocytes per gram of feces were conducted using MacMaster's egg counting technique. The oocytes were repeatedly examined for micrometery (Soulsby, 2005). The species identification was based on morphology of oocysts and eggs (Noor *et al*., 2021).

Blood sampling and endoparasite analysis

Blood samples were collected from 480 captive birds and 480 wild birds, 120 samples of each bird species and 120 from each selected districts *viz*., Bahawalpur, Khanewal, Okara, Kasur, Lahore, Sargodha, Chakwal and Rawalpindi from April 2021 to December 2021. We captured birds using mist nets and cleaned the area, inserted the insulin needle into the brachial vein to take 50–100µl of whole blood into the syringe. Transferred the blood to an anticoagulant-treated vial (EDTA tube), labelled it with the bird's identification number, and released the bird after it has fully recovered. These blood samples were immediately preserved into Queens's buffer. These preserved blood samples were brought to laboratory of the Department of Wildlife and Ecology and viewed under microscope (Das *et al*., 2020).

Microscopic examination

Two blood smears of each host were prepared and fixed with methanol. Staining was performed using Giemsa and targeted parasites were screened. All smears were examined using stereo microscope at high magnification (x1000) (Valkiunas, 2004).

Parasitic prevalence

Prevalence of ectoparasites and endoparasites was checked with respect to bird species, temperature, sampling site and along altitude.

Data analysis

Data regarding parasites was collected in spreadsheets (Excel 2010; Microsoft, Washington) and analyzed by one-way ANOVA and chi-squared test of independence using SPSS version 21.0 software (IBM, USA).

RESULTS

Total 480 captive and 480 wild birds were screened, Helminth species of parasites observed were nematodes species such as *Syngamus trachea*, *Allodopa suctoria*, *C. anatis*, *Heterakis gallinarum*, *Capillaria annulata* and *Ascaridia galli*; trematodes species such as *Prosthogonimus ovatus* and *Prosthogonimus macrorchis*; cestode species *Raillietina echinobothrida* and protozoan parasitic species *Giardia lamblia*, *Eimeria maxima* and *Histomonas meleagridis*. Collected 120 fecal and 120 blood samples of peafowls, ring-necked pheasants, turkeys, captive pigeons, sparrows, crows, mynas and wild pigeons were subjected to analyze prevalence of endoparasites as results compared in Table I.

Table I. Fecal parasites of different captive and wild bird species, their life cycle, morphological characters, sampling organ/tissue, clinical diagnosis and control measure.

Parasites	Life cycle	Morphological characters	Sampling organ/ tissue	Clinical diagnosis	Control measures
Trematodes					
Prosthogonimus ovatus	Indirect	Length 8-9mm; egg size 22-24 µm	Rectum and cloaca	Lay soft shelled eggs, milky discharge from cloaca	Control of secondary host
Prosthogonimus macrorchis	Indirect	Length 7-9 mm; egg size 20µm	Intestine	Thriftiness, abdominal disorder and retarded growth	Keep away from moisture area and ensure sanitary practices
Protozoa					
Giardia lamblia	Direct	Length 11-14µm; width 7-10µm in width. Cyst is dormant. Two forms Trophozoite is active form and	Intestinal tract	Weight loss, Diarrhoea is foul smelling, scratching and preening	Use cleaned drinking bottle. Use boiled and cooled water.
Eimeria maxima	Direct	Three developmental Stages; schizonts, gamonts and oocysts.	Small intestine	Bloody diarrhoea, Cause catarrhalic or haemorrhagic enteritis	Continuous medication is given through food and water. Sulfonamides is most common.
Histomonas meleagridis	Direct	Two forms: A tissue-dwelling amoebic form and a caecal lumen	Liver and Caeca	Penetration from blood to liver causes serious infection	Dimetridazole is recommended to treat histomonosis.
Cestode					
Raillietina echinobothrida	Indirect	Length 10-25cm; Egg size 74-93µm	Small intestine	Abdominal disorder and retarded growth	Control intermediate host
Nematodes					
Capillaria annulata	Direct/ indirect	Male 15-25mm; Female 37-80mm; eggs -30×70µm	Esophagus and crop mucosa	Infect in lining between crop and esophagus	Strict hygiene of drinker and feeder; restrict their habitat of humid ares
Ascaridia galli	Indirect	Male 15-25mm; Female 37-80mm; eggs -30×70µm	Small intestine	Wings detachment, loss appetite, pale wattles and combs, enteritis and unthriftiness	Anthelmintics are used, avoid to moisture content and Pasteur rotation
Syngamus trachea	Direct/ indirect	Female (5-20mm) are large in size than male (2-6mm); red coloured medium sized worms	Trachea and lungs	Respiratory disorders like sneezing and coughing, mucus block trachea causing severe mortality	Make ensure dried bird's bed and change it regularly
Capillaria anatis	Direct/ indirect	Males are 15 to 25 mm, females are 37 to 80 mm,and eggs are ~30x70 micrometer	Cecum	Diarrhoea	Anthelmintics are used

Table II. Blood parasites, their life cycle, morphological features, isolation organ/tissue, clinical diagnosis and control measures.

Parasite	Life cycle	Isolation cell/s	Morphological features	Clinical diagnosis	Control measures
Leucocytozoon simond	Indirect	Erythrocyte and leucocyte	Oval, mature gametocyte 14-22 µm. Gametocyte is elongated when found in leukocytes and round when found in erythrocytes.	The animals are anorectic, listless, anaemic and ave a labored breathing. CNS symptoms.	Medication is used in combination form pyrimethamine (1ppm) and sulfadimethoxine (10ppm) in the feed treatment mostly is not effective.
Plasmodium juxtanucleare	Indirect	Erythrocyte	Round oval or irregular in shape mature gametocyte is 15.5µm	Weight loss which causes death	Treatment is difficult in birds because duration of disease is 2 to 3 days.
Aegyptinella pullorum	Indirect	Erythrocyte	Small 5-10µm, round to oval bodies.	Diarrhea, ruffled feather birds may become anorectic and droopy	Biosecurity measures should be taken to reduce the introduction

Table III. Ectoparasites, their prediction sites, morphology, life cycle and clinical diagnosis.

Parasite	Life cycle	Isolation site	Morphological features	Clinical diagnosis	Control measures
Dermanyssus gallinae	Direct	Skin	The color of adult female mites is grey to deep red and size is 1 mm in length.	Anaemia, Reduction in egg production and itching effect may change bird behaviour.	Cracks and crevices should be filled in house should be clean and spray should be used.
Args persicus	Direct	Skin	Soft bodied tick. The size of female is 10 x 6 mm	Anaemia, weight loss, paralysis and depression.	Houses should be cleaned, walls, ceilings and cracks should be sprayed with carbaryl.

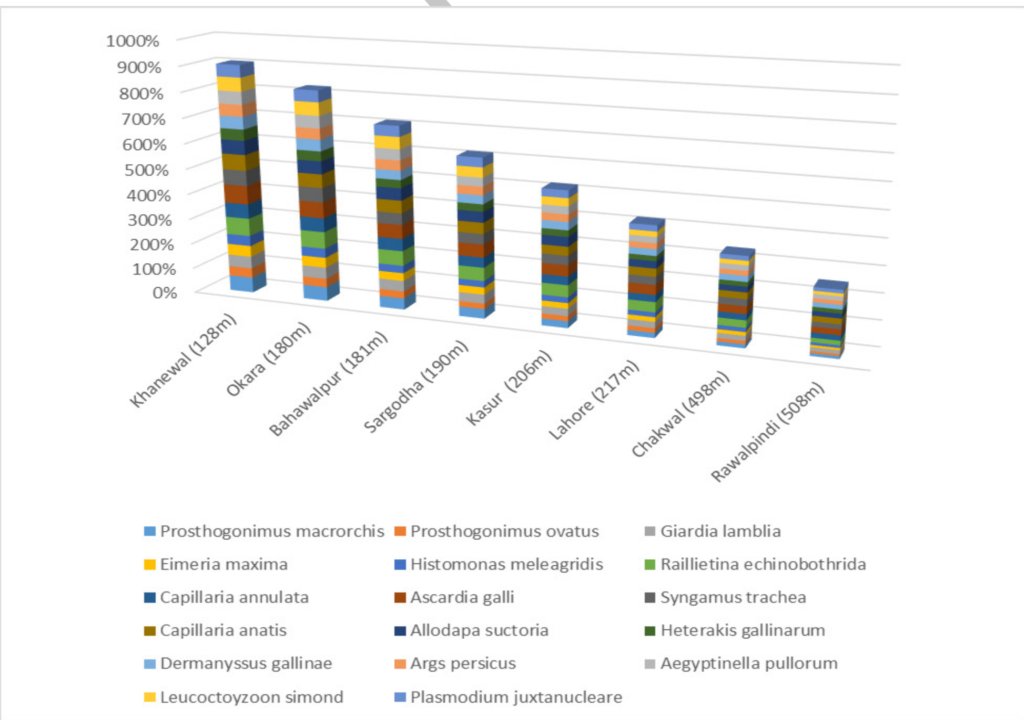

Fig. 1. Showing parasitic prevalence with respect to elevation gradient.

Table IV. Parasitic prevalence (%) with respect to temperature of each month.

Parasite	April (26°C)	May (28°C)	June (31°C)	July (39°C)	August (37.7°C)	September (29°C)	October (27°C)	November (25°C)	December (20°C)
Prosthogonimus macrorchis	29	41	45	51	49	43	34	23	15
Prosthogonimus ovatus	18	23	28	34	31	25	20	15	9
Giardia lamblia	23	33	36	55	51	34	27	20	13
Eimeria maxima	17	25	27	43	38	26	19	13	8
Histomonas meleagridis	13	17	20	36	26	18	13	11	6
Raillietina echinobothrida	43	52	60	68	65	56	47	36	20
Capillaria annulata	31	40	47	57	54	44	34	27	17
Ascaridia galli	37	48	57	66	62	52	43	29	18
Syngamus trachea	34	43	48	56	51	46	38	30	16
Capillaria anatis	30	41	49	52	45	44	35	25	14
Allodapa suctoria	27	37	43	50	48	40	31	22	12
Heterakis gallinarum	18	23	28	36	31	26	21	14	10
Dermanyssus gallinae	24	31	38	45	43	33	27	18	12
Args persicus	21	32	38	42	40	36	25	17	10
Aegyptinella pullorum	19	30	37	48	42	34	23	13	9
Leucocytozoon simondi	17	27	33	41	36	30	20	12	8
Plasmodium juxtanucleare	28	33	38	49	46	36	29	22	11

Total 136 (37.8%) birds were found positive with presence of one or more parasites. Statistical analysis showed positive relationship between parasitic prevalence and temperature. Maximum parasitic prevalence was recorded in months of dry season. Total 17 endoparasite species (3 species from blood samples and 14 from fecal samples), were observed. Two ectoparasitic species such as *Args persicus* (fowl ticks) and *Dermanyssus gallinae* (mite), were inspected with 44% and 43% prevalence, respectively. Results recorded variation in parasitic prevalence of ectoparasites and endoparasites. Turkeys showed maximum prevalence of *Raillietina echinobothrida* (78%) followed by captive pigeons (72%), sparrows (66%), ring-necked pheasants (55%), peafowls 53%), mynas, crows (48%), and minimum prevalence was recorded in wild pigeon (*H. meleagridis*, 8%). Results of prevalence of ectoparasites and endoparasites are depicted in Tables IV-VI.

Parasites grow maximum at high temperature, that is the reason maximum prevalence was recorded at 39 °C in July 2021 in *R. echinobothrida* (68%) followed by *A. galli* (66%), *C. annulata* (57%) and *Syngamus trachea* (56%). Similarly, minimum parasitic prevalence was recorded at low temperature, 20 °C in December 2021 in *Histomonas meleagridis* (6%) followed by *Eimeria maxima* (8%), *Leucocytozoon simondi* (8%), *Prosthogonimus ovatus* (9%) and *Aegyptinella pullorum* (9%). Increase in elevation level causes decrease in parasitic prevalence that is why captive and wild birds distributed in lowland areas, had more parasitic prevalence in comparison of birds found in upland areas. Maximum prevalence was recorded at the lowest elevation range, 128m in captive and wild birds sampled from Khanewal which was 73% in *Raillietina echinobothrida*, 66% at 180m in Okara, 58% at 181m (Bahawalpur), 52% at 190m (Sargodha), 46% at 206m (Kasur), 38% at 217m (Lahore), 29% (*A. galli*) at 498m (Chakwal) and minimum prevalence was recorded at the highest range, 508m in birds sampled from Rawalpindi which was recorded as 8% (*Histomonas meleagridis*). Parasitic prevalence with respect to variation in temperature and elevation level is shown in Tables V and VI, respectively.

Results of parasitic prevalence of three blood parasites showed 44% prevalence of *Leucocytozoon simond*, 49% of *Aegyptinella pullorum* and 47% that of *Plasmodium juxtanucleare* in turkeys. Parasitic prevalence of six fecal parasites of nematodes was recorded as 51% (*Allodapa suctoria*), 36% (*Heterakis gallinarum*), 69% (*Ascaridia galli*), 59% (*Capillaria annulata*), 53% (*Capillaria anatis*) and 55% (*Syngamus trachea*). Similarly, parasitic prevalence of two fecal parasites of trematodes, was recorded as 58% (*Prosthogonimus macrorchis*) and

36% (*Prosthogonimus ovatus*). 78% prevalence was recorded for cestode species *Raillietina echinobothrida*. Corpological analysis of three protozoan species showed prevalence as 43% *Eimeria maxima*, 53% *Giardia lamblia* and 28% *Histomonas meleagridis* in Turkeys (Figs. I-III). Parasitic prevalence of two ectoparasites was recorded as 43% for *Dermanyssus gallinae* and 44% *Args persicus* as depicted in Table VI.

Table V. Parasitic prevalence (%) with respect to elevation of each district.

Parasite	Khanewal (128m)	Okara (180m)	Bahawalpur (181m)	Sargodha (190m)	Kasur (206m)	Lahore (217m)	Chakwal (498m)	Rawalpindi (508m)
Prosthogonimus macrorchis	61	55	44	38	27	20	15	11
Prosthogonimus ovatus	38	34	28	22	20	18	13	9
Giardia lamblia	48	45	42	35	28	24	19	14
Eimeria maxima	44	40	31	28	22	18	14	10
Histomonas meleagridis	41	37	29	25	23	18	16	8
Raillietina echinobothrida	73	66	58	52	46	38	28	17
Capillaria annulata	58	55	48	39	33	27	23	19
Ascaridia galli	70	63	54	50	43	38	29	22
Syngamus trachea	61	57	45	40	36	30	26	18
Capillaria anatis	63	53	49	43	34	31	25	21
Allodapa suctoria	56	51	48	42	37	28	21	18
Heterakis gallinarum	44	38	32	28	25	19	18	15
Dermanyssus gallinae	49	45	36	33	31	25	22	17
Args persicus	47	43	38	33	28	22	18	14
Aegyptinella pullorum	51	48	43	34	29	23	20	16
Leucocytozoon simondi	54	52	47	38	31	20	17	11
Plasmodium juxtanucleare	48	45	42	37	29	23	18	13

Table VI. Parasitic prevalence (%) with respect to each bird.

Parasite	Turkey	Captive pigeon	Sparrow	Ring-necked pheasant	Peafowl	Myna	Crow	Wild pigeon
Prosthogonimus macrorchis	58	53	48	45	43	40	32	27
Prosthogonimus ovatus	36	33	31	28	25	23	20	18
Giardia lamblia	53	45	39	37	35	33	30	26
Eimeria maxima	43	37	31	28	22	19	18	15
Histomonas meleagridis	28	26	21	18	16	13	11	8
Raillietina echinobothrida	78	72	66	55	53	48	45	41
Capillaria annulata	59	51	45	40	36	33	30	26
Ascaridia galli	69	63	55	51	48	43	36	27
Syngamus trachea	55	52	49	47	45	43	37	33
Capillaria anatis	53	49	45	43	40	37	35	32
Allodapa suctoria	51	47	45	43	38	33	28	26
Heterakis gallinarum	36	35	33	32	28	26	22	18
Dermanyssus gallinae	43	40	37	35	32	28	26	25
Args persicus	44	39	38	34	32	31	30	28
Aegyptinella pullorum	49	40	38	38	28	25	24	19
Leucocytozoon simond	44	43	42	41	34	23	18	13
Plasmodium juxtanucleare	47	40	38	36	35	33	29	27

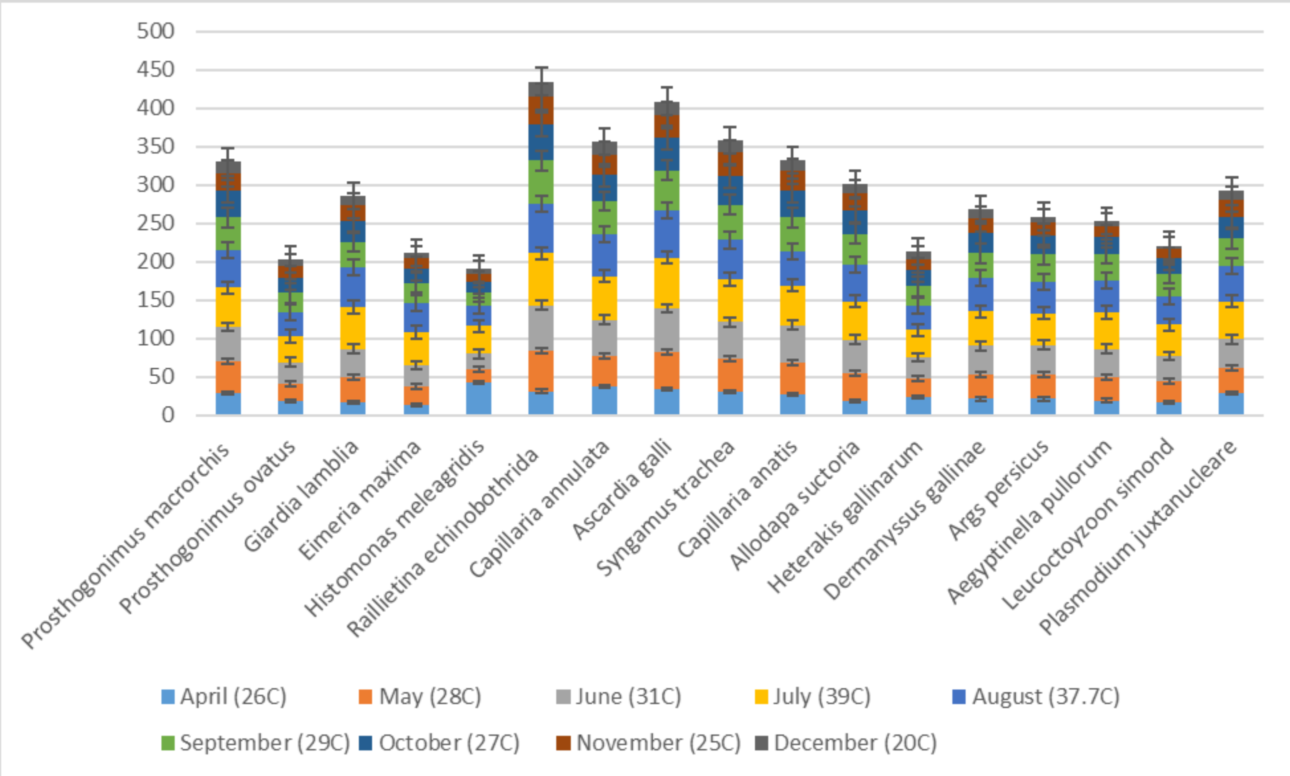

Fig. 2. Parasitic prevalence with respect to variation in temperature.

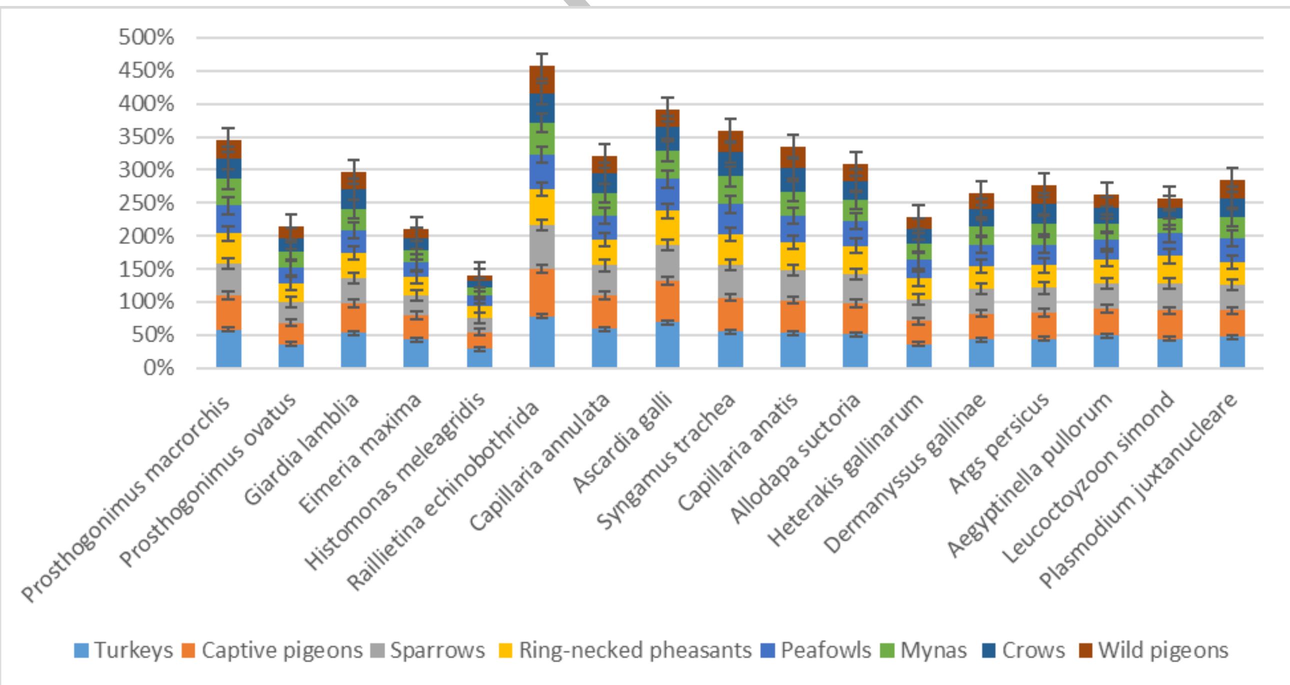

Fig. 3. Parasitic prevalence with respect to bird species.

DISCUSSION

Parasites greatly affect behavior and ecological interactions of birds (Abdu *et al*., 2022). Avian parasitic species cause decline in bird population and mass mortality in captive birds (Coker *et al*., 2017). This study indicates that out of 17 isolated parasites, *Raillietina echinobothrida* showed maximum prevalence (78%) in Turkeys sampled from Khanewal (128m) in the month of July at 39°C and minimum prevalence was showed by *Histomonas meleagridis* (8%) in wild pigeon sampled from Rawalpindi (508m) in the month of December at 20°C. Parasitic prevalence of *R. echinobothrida* was higher than recorded previously by (Noor *et al*., 2021) which was 72%. We recorded overall parasitic prevalence as 37.8% which was also higher than recorded in a previous study by (Zamora-Vilchis *et al*., 2012) who recorded 32.3%.

Avian parasites have widespread distribution and affected a wide variety of avian families ranging from acute to severe infections resulting fatal diseases in some cases (Meister *et al*., 2023). In current study, results showed strong association between temperature and parasitic prevalence in selected captive and wild birds. We found high prevalence in captive and wild birds distributed in lowland climatic zones (0-200m) especially in Khanewal (128m) where maximum prevalence, 73%, was recorded in *Raillietina echinobothrida* while we recorded low parasitic prevalence in wild and captive birds sampled from upland zones (200-600m) especially in Rawalpindi (508m) where maximum prevalence, 22%, was recorded in *A. galli*. This difference in high parasitic prevalence in lowland zones and upload zones was due to high temperature in lowland zone and low temperature in upland zones as temperature decreases with the increase in elevation. There is no any study performed to check impact of variation in temperature on parasitic prevalence, so we performed unique study in this context (Webb and Tracey, 1981; Yousafzai *et al*., 2021; Kleinschmidt *et al*., 2022). Parasitic prevalence are well documented on the basis of temporal and spatial dissimilarities. Intermediate hosts have different parasitic prevalence. There is a wide variety and vast geographic distribution of helminth species in Asia (Niranjan *et al*., 2020).

In current study, nine helminth species of parasites were observed. Eight of these nine, were nematodes species such as *S. trachea*, *A. suctoria*, *C. anatis*, *H. gallinarum*, *C. annulata* and *A. galli* while two trematodes species such as *P. ovatus* and one cestode species *R. echinobothrida*. Three parasites such as *A. galli*, *C. annulata* and *H. gallinarum*, are considered as major parasites in poultry industry which spread infectious diseases such as ascariodiosis and cestodiosis (Wongrak *et al*., 2014). Almost hundred helminth species are known so far isolated from captive and wild bird species. These parasitic species affect birds' growth and egg laying badly. Nematodes parasitic species usually cause severe infections of gastrointestinal tract of birds (Al-Quraishi *et al*. 2020). Hasan *et al*. (2018) also isolated *A. galli* from turkeys and recorded its prevalence as 12.5% which was very low as compared to prevalence recorded in our study as 69%. They recorded 25% occurrence of *E. maxima* in turkeys while we recorded as 43% in our study. Ferrell *et al*. (2009) recorded *A. galli* (16%), *E. tenella* (18%) and *E. acervulina* (12%) in game birds such as turkey. Fecchio *et al*. (2017) reported 43% prevalence of *A. galli* and 12% of *Eimeria* spp. in love birds. However, Borecka *et al*. (2013) recorded *A. galli* (34%) and *Eimeria* spp. (23%) in Poland from game birds. Dubiec and Cichon (2001) found *A. galli* (42%) and *H. gallinae* (13%) in Saudi Arabia from love birds.

Parsani *et al*. (2001) recorded *A. galli* (28%), *Eimeria* spp. (17%), and *H. gallinarum* (63%) from captive birds in Gujrat, India. Dashe and Berhanu (2020) also detected 100% *Eimeria* spp. in December and 66.7% in April, 50% *Ascaridia* spp. in December and 33.3% in April. In another study by Van Hemert *et al*. (2019), they recorded prevalence of Leucocytozoon and Plasmodium as 53.8% and 9.7% respectively while we recorded 44% and 47% prevalence of Leucocytozoon and Plasmodium, respectively. According to current and previous studies, parasitic prevalence is distributed in wide variety of captive and wild bird species worldwide. But variation in their prevalence is due to their different climatic conditions, geographical distribution, sex, age, seasons, method of study, treatment and sample size (Kumar *et al*., 2019).

R. echinobothrida is one of the most significant helminth parasites that has worldwide prevalence (Li *et al*., 2009). Current study recorded maximum prevalence of *R. echinobothrida* in turkeys (78%) and captive pigeons (72%) sampled from Khanewal (128m) at 39 ºC in July. *R. echinobothrida* was observed as a rounded headed, more than 25 cm long white color, wide and short neck that has 1-25 cm length (Mu *et al*., 2009). Dakhil and Al-Musaedi (2022) recorded 73.3% prevalence of *R. echinobothrida* in wild pigeons which was 1% higher than our recorded prevalence which may be due to different environmental conditions such as variation in temperature. Jasim *et al*. (2019) recorded 30.43% prevalence of *R. echinobothrida* in wild pigeon which was significantly lower than our recorded results.

In the current study, we recorded 69% and 63% prevalence of *A. galli* in infected turkeys and pigeons, respectively. While in a previous study, parasitological examination revealed 50% and 40% *A. galli* prevalence in infected and healthy turkeys, respectively. The morphological characterization revealed *A. galli* as semitransparent and yellowish white that was 0.062 mm long and 0.045 mm wide while *A. galli* egg was oval in shape (Tables II and III) (Mervat *et al*., 2020). Hamzah *et al*. (2020) recorded 12.5% gastrointestinal ascariasis caused by *Ascaridia* in healthy domestic pigeons. Abdel Rahman *et al*. (2019) reported 25% prevalence of *A. galli* in pigeons in Egypt. Yousaf *et al*. (2019) recorded 28.64% prevalence of *A. galli* which was very low in comparison with our findings. Salem *et al*. (2022) also recorded 63.1% prevalence of *Ascaridia* in pigeon comparatively lower than our recorded values. Faraj and Al-Amery (2020) have recorded very low prevalence 15.62% caused by *Ascaridia* in pigeons.

In the current study we recorded a significant infection rate caused by *Capillaria* nematode species which was 59% prevalence of *C. annulata* and 53% of *C. anatis* in turkeys while 51% and 49% in pigeons, respectively. In previous studies, Malik *et al*. (2020) recorded 73.3% prevalence of *Capillaria* in infected pigeons in Narowal (Punjab).

CONCLUSION

Current study identified three species of Haemoparasite, six nematodes, one cestode, three protozoan and two trematodes in fecal and blood samples of *Columba livia domestica*, *Passer domesticus*, *Phasianus colchicus*, *Pavo cristatus*, *Acridotheres tristis* and *Corvus splendens*. Proper medication, vaccination and sanitation of bird's enclosures are recommended to avoid parasitic infection. Parasites have a significant impact on the health and immunity of both captive and wild birds. Bird's sex, age, treatment, and season affect parasitic prevalence.

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IRB approval

The research work was approved by Departmental Board of Studies of Department of Wildlife and Ecology, University of Veterinary and Animal Sciences, Lahore, Pakistan.

Ethical statement

The research work was approved by ethical committee of University of Veterinary and Animal Sciences, Lahore, Pakistan.

Statement of conflict of interest

All the authors declare that they have no conflicts of interest. This work is neither published elsewhere nor under consideration for publication. All the authors approved its submission to this journal.

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