

Causes of Morbidity and Mortality in Wild Animals and Birds at Captive Breeding Facilities of Punjab, Pakistan

Zahra Hussain, Zulfiqar Ali* and Rida Ahmad

Environmental Health and Wildlife Laboratory, Institute of Zoology, University of the Punjab, Lahore, Pakistan

ABSTRACT

Captive breeding of wild animals can enhance conservation of species, while the prevalence of diseases and other pathological conditions is a very common issue in captive animals and birds. The present study investigated the prevalence of different diseases and health conditions among animal and bird species at 10 captive breeding facilities of Punjab, Pakistan. For this purpose, three-year data (2017-2019), regarding diseases and pathological conditions was collected from treatment register, stud books and post-mortem reports. Most prevalent health issues in animals were infectious diseases 26%, followed by generalized conditions 23%, gastrointestinal issues 17%, and cardiovascular issues 7%. In animals, out of total 102 different diseases and pathological conditions, the maximum variation was noted in mouflon sheep (*Ovis orientalis orientalis*), hog deer (*Axis porcinus*) and spotted deer (*Axis axis*). In birds, 37% infectious diseases, 24% generalized conditions, 15% gastrointestinal and 9% respiratory issues were recorded. Among infectious diseases, salmonellosis, infectious coryza and colibacillosis were most abundant with 34, 34 and 29 cases respectively. Out of 99 different diseases and pathological conditions in birds, maximum variety was recorded in ring-necked pheasant (*Phasianus colchicus*), black-shouldered peafowl (*Pavo cristatus*) and green pheasant (*Phasianus versicolor*). Comparison of different study sites revealed that Lahore Zoo had the highest disease prevalence in animals with significance value 0.002 ($p < 0.05$). To reduce prevalence of diseases and health issues, various strategies and guidelines given by international authorities such as Association of Zoos and Aquariums and European Association of Zoos and Aquaria should be adopted and implemented.

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Authors' Contribution

ZH and ZA conceptualized the study. ZH collected the data from field. ZH and RA analyzed the data and drafted the manuscript. ZA reviewed and improved the manuscript.

Key words

Captive breeding, Pathological conditions, Post-mortem, Morbidity, Mortality

INTRODUCTION

Captive breeding can be defined as a process of breeding wild animals in wildlife parks and zoos, principally with the aim to aid in the conservation of species which face threats of extinction in their natural wild habitats and these efforts should aim towards maintaining a self-sustaining and healthy captive population (Wakchaure and Ganguly, 2016). Increased communication and awareness between wildlife veterinarians and the captive breeding institutes have brought various diseases to limelight, which were previously not reported and diagnosed (Cheeran, 2004). Over the past thirty years, improved veterinary care, husbandry and nutrition of animals living in captive environments has resulted in increased longevity of captive animals (Krebs *et al.*, 2018).

In captivity, the prevalence of diseases is a very common issue in animals which can happen due to unsuitable diet provision, poor hygiene in enclosures, lack of enrichment practices, psychological stress, injuries, and various other causes (Nemat, 2015). Captivity induced stress leads to depressed immunity of animals, eventually leading them vulnerable against different parasitic, viral, and bacterial infections (Moudgil and Singla, 2013). In the case of birds, stress factors like nutrition, introduction of new birds, breeding and overcrowding in the aviaries can significantly cause disease outbreaks. Infections can spread when multiple birds are kept together and have contact with each other (Joseph, 2003). Infectious diseases are an emerging threat to conservation of wildlife (Cunningham *et al.*, 2017).

Literature has shown that the pathological conditions related to captive animals can vary as compared to the animals belonging to the wild populations (Strong *et al.*, 2016). In natural environment, wild animals are in larger areas where they can be exposed to different parasites like helminths and protozoans, thus they usually can develop

* Corresponding author: zali.zool@pu.edu.pk, zali.zool@pu.edu.pk
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certain resistance against such infectious agents. But contrary to this, under captive environments such as in zoos, they live in smaller spaces and have little exposure to such agents, which can weaken their immunity to resist such infections (Muoria *et al.*, 2005). Parasites can also affect the productivity and well-being of captive wild animals, by increasing the level of stress and effecting the survival of captive animals (Kolapo and Jegede, 2017). While the infections caused by gastrointestinal parasites can also be a major health concern in the captive birds (Otegbade and Morenikeji, 2014).

With the help of post-mortem records, important data about health trends of captive animals is collected which can also help in taking future decisions regarding health care of living animals. To ensure the well-being of animals, the post-mortem examination should be carried on all dead animals in captivity (Scaglione *et al.*, 2019). These records are also important for scientific understanding of the disease process (Naidu, 2006) and the disease profile of captive species can be different from the wild counterparts (Courtenay and Santow, 1989). Disease can be “of concern” at captive facilities as it will put a direct risk of animal loss. Each captive facility (zoo, safari park, wildlife park, breeding center) will have different “disease of concern” depending on the location and species collection that may vary widely over time (Scaglione *et al.*, 2019).

The captive breeding in parks, zoological gardens and other similar institutions has been carried out around the globe as a conservation tool. Such successful practices of captive breeding have also been continued in Pakistan (Ali *et al.*, 2011). Punjab Wildlife and Parks Department is making efforts in the direction of captive breeding, propagation and management of wild animals and birds in the province of the Punjab (Maan *et al.*, 2016). There was a need for a comprehensive and cross institutional study regarding prevalence of diseases and different pathological conditions in captive animals and birds in Punjab, Pakistan. Therefore, this study was aimed to investigate the prevalence of various diseases and pathological conditions in animals and birds kept at 10 captive breeding facilities in Punjab and to investigate the overall health care and treatment facilities provided to these animals and birds at the selected captive breeding sites.

MATERIALS AND METHODS

Study sites

For the current study, the prevalence of diseases and other pathological conditions of animals and birds have been investigated in ten wildlife captive breeding facilities in Punjab between 2017 and 2019. The sites

included Lahore Zoological Garden, Safari Zoo Lahore, Jallo Wildlife Park, Changa Manga Wildlife Park, Gatwala Wildlife Park, Bahawalpur Zoo, Bansra Gali Murree Wildlife Park, Pirowal Wildlife Park, Vehari Wildlife Park and Lal Suhanra National Park (Fig. 1).

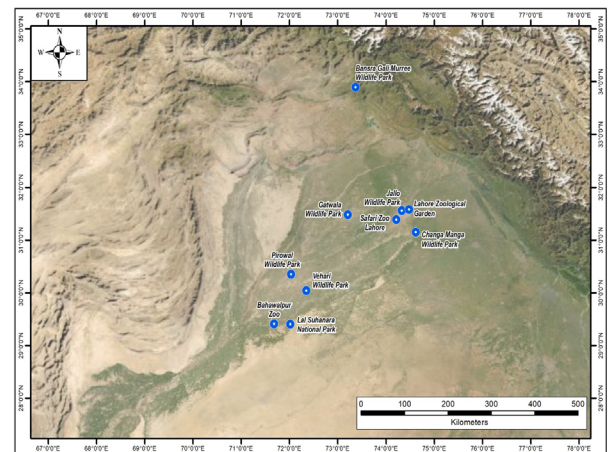


Fig. 1. Map of selected parks and zoos in Punjab.

Data collection

The sites were visited to obtain three-year data (from 2017 to 2019) regarding prevalence of diseases and other pathological conditions in animals and birds. The required information was acquired through stud books, treatment registers and post-mortem reports of all animals and birds, provided by the respective administration.

The captive animals and birds belonged to both genders and varying age. The causes of morbidity and mortality were studied for all species of animals and birds and could be considered under two broad categories viz., diseases and other pathological conditions with the help of literature and veterinarian's opinion. These categories were divided into sub-categories such as, infectious, respiratory, gastrointestinal, and cardiovascular issues. The sources of infectious agents were studied in detail and divided into bacterial, viral, fungal, protozoal, and parasitic infestation categories for detailed analysis.

Statistical analysis

The resulting data were statistically analyzed using SPSS (ver. 25.0). The association between the selected study sites with reference to prevalence of diseases and pathological conditions were assessed by applying one way-ANOVA test.

RESULTS

Diseases and pathological conditions in animals

A total of 102 different diseases and pathological conditions were recorded in captive animals (Supplementary Table S1). With respect to the overall prevalence of various pathological conditions and diseases in the selected captive breeding sites, Lahore Zoological Garden had the highest number of cases reported followed by Lal Suhanra National Park and Safari Zoo Lahore (Table I).

The highest prevalence was of infectious diseases, which constituted 26% of all diseases and pathological conditions (Fig. 2a). Around 49% of infections were caused by more than one infectious agent. Infestations were 20%, followed by bacterial diseases 19%. Protozoans were responsible for 6% of the infectious diseases and viral diseases were 3.66%. Prions as infecting agents were linked to 0.91% of the diseases (Fig. 2b).

The most prevalent bacterial disease in captive animals was tuberculosis with 10 cases (Fig. 2c), while among other infectious diseases, 50 cases of Pneumonia were studied, making it the most common infectious disease in captive animals (Fig. 2d). Among other bacterial diseases, infections like anthrax, salmonella, tetanus, *E. coli*, typhoid and caseous lymphadenitis were also seen in captive animals.

In non-bacterial infectious diseases, infestations had the second highest prevalence (20%) after pneumonia (Fig. 2d). Among parasites, liver fluke and round worms were specifically reported and in some cases the parasite was not specified. Other common non-bacterial infectious diseases included feline panleukopenia, bronchopneumonia and trypanomiasis. While malaria, coccidiosis, lymphadenitis, and chronic wasting disease were less prevalent with only one case reported for each.

Non-infectious diseases in captive animals included

hemorrhagic gastroenteritis, bronchitis, and lactic acidosis. While cancer and cancer related issues including tumor, skin cancer, and neoplasia were also encountered in the captive animal species.

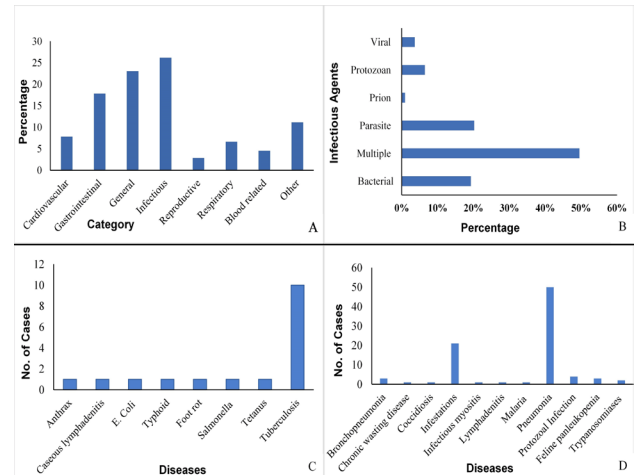


Fig. 2. (A) Prevalence of various diseases and pathological conditions of animals at selected captive breeding sites. (B) Sources of infectious diseases in captive animals. (C) Prevalence of bacterial diseases in captive animals at selected captive breeding sites. (D) Prevalence of diseases caused by viral, protozoal, prion, parasitic or multiple infectious agents.

Generalized health issues such as stress, lameness, dehydration, weakness, hypothermia, hyperthermia, anorexia, and heat stroke were 23%. Gastrointestinal issues constituted 17% of all pathological conditions among which diarrhea and enteritis were the most common with 29 and 20 cases, respectively. Cardiovascular issues were 7%, among which the heart failure and cardiac arrest were a leading cause of mortality in animals studied in pathology reports.

Table I. Number of diseases and pathological conditions studied in captive birds and animals.

	Baha-walpur Zoo	Bansra Gali Murree Wildlife Park	Pirowal Wildlife Park	Lal Suhanara National Park	Safari Zoo Lahore	Changa Manga Wildlife Park	Gatwala Wildlife Park	Lahore Zoological Garden	Jallo Wildlife Park	Vehari Wildlife Park
Animals										
Disease	4	2	3	31	17	9	4	38	6	8
Condition	20	16	16	43	40	18	16	100	7	17
Birds										
Disease	25	6	8	70	80	32	17	14	4	31
Condition	69	12	38	52	176	8	44	40	14	7

Among captive animals, respiratory issues, such as respiratory failure and respiratory distress accounted for 6% of all causes of morbidity, while the blood related conditions such as anemia, toxemia were 4%. In reproductive issues (2%), the most prevalent cases reported were of dystocia. Other health issues including hepatic, skin related conditions, cancer and related issues and metabolic disorders were also recorded but were found to be relatively less prevalent.

According to the statistical analysis, Lahore Zoo showed significant difference $p < 0.05$ (0.002) as compared to other sites in terms of number of reported pathological

conditions and diseases.

The causes of morbidity and mortality studied in animal species have been presented in [Tables II](#) and [III](#), respectively. Among animals, the highest number of causes of morbidity and mortality (36) were noted in Mouflon Sheep (*Ovis orientalis orientalis*), followed by Hog Deer (*Axis porcinus*) (28) and Spotted Deer (*Axis axis*) (22). In both African Lion (*Panthera leo*) and Blue Bull (*Boselaphus tragocamelus*), there were 21 causes of morbidity and mortality, while in Rhesus Monkey (*Macaca mulatta*), only 9 causes of morbidity and mortality were noted.

Table II. Causes of captive animals' morbidity in selected study sites.

Species	Number of diseases/ Pathological conditions	Causes of morbidity
Black bear (<i>Ursus thibetanus</i>)	2	Endoparasites, heat stress
Black buck (<i>Antilope cervicapra</i>)	9	Diarrhea, dystocia, heat stroke, heat stress, lameness, shivering, pneumonia, trypanosomiasis, tumor
Blue bull (<i>Boselaphus tragocamelus</i>)	10	Bradycardia, diarrhea, indigestion, L. acidosis, swelling on neck, trypanosomiasis, weakness, dullness
Chinkara (<i>Gazella g. bennettii</i>)	6	Breathing difficulty, enteritis, heat stroke, pneumonia, recumbent, weakness
Mugger crocodile (<i>Crocodylus palustris</i>)	4	Ectoparasites, endoparasites, blood protozoa, lameness
Hog deer (<i>Axis porcinus</i>)	11	Chronic wasting disease, diarrhea, weakness, dull and depressed, emaciation, endoparasites, ectoparasites, heat stress, babesiosis, pneumonia, severe acidosis
African lion (<i>Panthera leo</i>)	11	Alopecia, dullness, diarrhea, gastrointestinal issues, general debility, myiasis, neuromuscular disorder, vomiting, weakness, hindquarter paralysis, worm infestation
Mouflon sheep (<i>Ovis orientalis orientalis</i>)	15	Anorexia, coccidiosis, colibacillosis, weakness, diarrhea, cough, dystocia, fasciolosis, gastrointestinal disorder, lameness, liver fluke infestation, endoparasites, pneumonia, respiratory distress, skin infection
Puma (<i>Puma concolor</i>)	3	Dullness, indigestion, suspected hygroma
Rabbit (<i>Oryctolagus cuniculus</i>)	2	Dermatitis, laziness
Red deer (<i>Cervus elaphus</i>)	2	Anorexia, weakness
Rhesus monkey (<i>Macaca mulatta</i>)	4	Alopecia, bacterial infection, hypothermic, weakness, anorexia
Samber deer (<i>Rusa unicolor</i>)	6	Internal parasites, diarrhea, dullness, dehydration, recumbency, low temperature
Siberian tiger (<i>Panthera tigris tigris</i>)	3	Gastrointestinal issue, hair fall, abnormal licking behavior
Spotted deer (<i>Axis axis</i>)	11	Eye infection, dull and depressed, high temperature, enteritis, hypothermia, lethargic, pneumonia, respiratory problem, shivering, tuberculosis, worm infestation
Brown bengal tiger (<i>Panthera tigris</i>)	1	Right forelimb lameness
Punjab urial (<i>Ovis vignei punjabiensis</i>)	7	diarrhea, dullness, hyperkeratosis, protozoal infection, trypanosomiasis, weakness, high temperature
Yak (<i>Bos grunniens</i>)	5	Nasal discharge, foot rot, low body temperature, weakness, off-feed

Table III. Causes of captive animals' mortality in selected study sites.

Species	Number of diseases/ Pathological conditions	Causes of mortality
Addax (<i>Addax nasomaculatus</i>)	1	Pneumonia
African lion (<i>Panthera leo</i>)	11	Anemia, atresia ani, fluid aspiration, gastroenteritis, hypothermia, pulmonary congestion, respiratory distress, respiratory failure, congestive heart failure, feline panleukopenia, hemorrhagic enteritis
Brown bengal tiger (<i>Panthera tigris</i>)	3	Blood protozoans, neoplasia, ovarian tumor
Black bear (<i>Ursus thibetanus</i>)	1	Acute heart failure
Black buck (<i>Antilope cervicapra</i>)	17	Ascites, bronchopneumonia, dystocia, enteritis, epistaxis, gastroenteritis, heart failure, heart stroke, heat stress, hemorrhagic enteritis, lymphadenitis, myiasis, pneumonia, premature birth, respiratory failure, septicemia
Blue bull (<i>Boselaphus tragocamelus</i>)	10	Coryza, enteritis, infectious myositis, pneumonia, ruminal impaction, skin cancer, tetanus, toxemia, trypanomiasis, bronchopneumonia
Arabian camel (<i>Camelus dromedarius</i>)	1	Infection of rumen
Capuchin monkey (<i>Cebus imitator</i>)	1	Tuberculosis
Chimpanzee (<i>Pan troglodytes</i>)	1	Severe anemia
Chinkara deer (<i>Gazella bennettii</i>)	12	Enteritis, contaminated grass in stomach, dystocia, heart failure, myiasis, septicemic fever, pneumonia, respiratory failure, septicemia, cardiovascular failure, tuberculosis
Common palm civet (<i>Paradoxurus hermaphroditus</i>)	2	Congested lungs, feline panleukopenia
Common krait (<i>Bungarus caeruleus</i>)	1	Pneumonia
Muggar crocodile (<i>Crocodylus palustris</i>)	2	Necrotic enteritis, hemorrhagic enteritis
African bush elephant (<i>Loxodonta africana</i>)	1	Cardiac arrest
Fallow deer (<i>Dama dama</i>)	1	Caseous lymphadenitis
Guinea pig (<i>Cavia porcellus</i>)	4	Ascites, congestion of internal organs, hemorrhagic enteritis, pneumonia
Hog deer (<i>Axis porcinus</i>)	17	Anemia, ascites, bacterial infection (anthrax), blood protozoa, bronchopneumonia, cardiac arrest, diarrhea, hemorrhagic enteritis, hepatitis, hydatid cyst, hypovolemic shock, nervous disorder, peritonitis and lung congestion, lung congestion, pneumonia, respiratory collapse, septicemia
Indian rock python (<i>Python molurus</i>)	2	Round worm infestation, ulcerative gastroenteritis
Golden jackal (<i>Canis aureus</i>)	2	Bronchitis, salmonella infection
Common leopard (<i>Panthera pardus</i>)	1	Cardiac arrest
Llama (<i>Lama guanicoe pacos</i>)	1	Spinal cord compression
Rhesus monkey (<i>Macaca mulatta</i>)	5	Cardiac arrest, dystocia, heart failure, respiratory failure, diarrhea
Mouflon sheep (<i>Ovis orientalis orientalis</i>)	21	Acute strangulation (intestinal), anorexia, ascites, chronic hepatic failure, congested heart failure, diarrhea, dystocia, enteritis, hypothermia, liver fluke infestation, mycobacterium tuberculosis, pneumonia, pulmonary congestion, pulmonary edema, respiratory distress, respiratory failure, suspected peritonitis, toxemia, urine retention, weakness
Olive baboon (<i>Papio anubis</i>)	1	<i>E. coli</i> infection

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Species	Number of diseases/ Pathological conditions	Causes of mortality
Puma (<i>Puma concolor</i>)	2	Multiple organ failure, cardiac arrest
Punjab urial (<i>Ovis vignei Punjabiensis</i>)	7	Coccidiosis, congested heart failure, dehydration, enteritis, hemorrhagic intestinal mucosa, pneumonia, protozoal infection
Rabbit (<i>Oryctolagus cuniculus</i>)	3	Ascites, congested lungs, enteritis
Red deer (<i>Cervus elaphus</i>)	3	Anorexia, enteritis, heart failure
Russel's viper (<i>Daboia russelii</i>)	2	Septicemia, pneumonia
Samber deer (<i>Rusa unicolor</i>)	2	Pneumonia, cardiac arrest
Saw scaled viper (<i>Echis carinatus</i>)	1	Pneumonia
Sika deer (<i>Cervus nippon</i>)	1	Pulmonary tuberculosis
Spotted deer (<i>Axis axis</i>)	11	diarrhea, dystocia, enteritis, pneumonia, respiratory distress, respiratory failure, septicemia, toxemia, tuberculosis, tympanites, hemorrhagic enteritis
Tortoise (<i>Chelonoidis nigra</i>)	1	Congested heart failure
Water snake (<i>Pelamis platurus</i>)	1	Gastrointestinal tract compaction
Water turtle (<i>Malaclemys terrapin</i>)	1	Enteritis
White bengal tiger (<i>Panthera tigris</i>)	1	Blood protozoans
African white lion (<i>Panthera leo</i>)	2	Peritonitis, tuberculosis
Yak (<i>Bos grunniens</i>)	2	Congestive heart failure, enteritic fever
Zebra (<i>Equus burchelli</i>)	1	Septicemia

Diseases and pathological conditions in birds

A total of 98 different diseases and pathological conditions were reported in the avian species of the selected captive breeding sites (Supplementary Table S2). Comparison of the prevalence (Table I) shows that Safari Zoo Lahore had the highest prevalence of diseases and pathological conditions in the bird species kept in captivity but there was no significant difference regarding the prevalence of diseases and pathological conditions among the selected study sites.

The infectious diseases was the most common issue among birds, constituting around 37% of all conditions and diseases in the selected study sites. General pathological conditions were 24% and gastrointestinal issues 19%. Respiratory complications were around 15%, 3% health issues were related to excretory system, followed by 3% blood related issues and disorders, and 2% reproductive issues (Fig. 3a).

Among infectious diseases, bacterial diseases were around 53% while 19% were viral diseases (Fig. 3b). Parasite, fungal and protozoal diseases, all constituted 3% each among the infectious diseases, while 15% diseases were such that could be due to multiple infectious agents. Salmonellosis and infectious coryza (34 cases each) were the most prevalent infectious diseases in birds, followed by colibacillosis (29 cases) in the second place (Fig. 3c). Non-bacterial infectious diseases included Newcastle virus, avian influenza, and coccidiosis (Fig. 3d). Parasitic worm infestations were also reported in birds. The causes of morbidity and mortality studied in bird species have been

presented in Tables IV and V respectively. Among birds, the highest number of causes of morbidity and mortality (46) were noted in ring-necked pheasant (*Phasianus colchicus*), followed by black-shouldered peafowl (*Pavo cristatus*, 42) and green pheasant (*Phasianus versicolor*, 41). Among common species, lowest number of causes of morbidity and mortality were noted in Guinea peafowl (*Numida meleagris*).

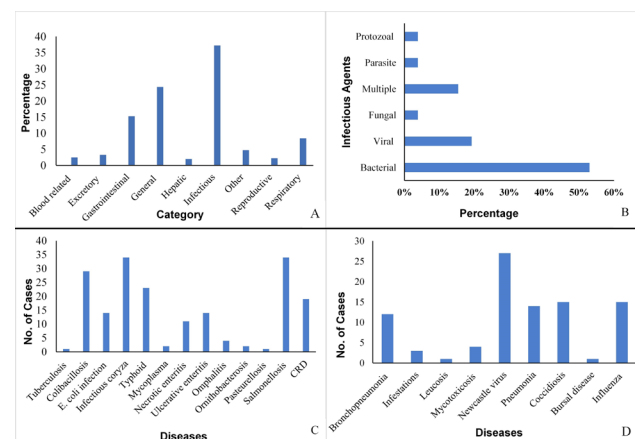


Fig. 3. (A) Prevalence of various diseases and pathological conditions of birds at selected captive breeding sites. (B) Sources of infectious diseases in captive birds. (C) Prevalence of bacterial diseases in captive birds. (D) Prevalence of diseases caused by viral, protozoal, fungal, parasitic, or multiple infectious agents.

Table IV. Causes of captive birds' morbidity in selected study sites.

Species	Number of diseases/ Pathological conditions	Causes of morbidity
Black partridge (<i>Melanoperdix niger</i>)	2	Dullness, avian tuberculosis
Black shouldered peafowl (<i>Pavo cristatus</i>)	13	Dull and depressed, enteritis, fever, anorexia, caseous mass on infraorbital sinus, coryza, respiratory distress, sinusitis, rhinitis, sneezing, ruffled feathers, lame, typhoid
Black swan (<i>Cygnus atratus</i>)	2	Feather loss, hind leg swelling
Swinhoe's pheasant (<i>Lophura swinhoii</i>)	4	Allergy, dull and depressed, weakness, coccidiosis
Caroline duck (<i>Aix sponsa</i>)	3	Respiratory distress, recumbency, spraddle leg
Chukar partridge (<i>Alectoris chukor</i>)	7	Anorexia, diarrhea, respiratory distress, dull and depressed, enteritis, lameness, limping, unable to stand
Common geese (<i>Anser anser domesticus</i>)	5	Cornered, stress, weakness, anorexia, respiratory distress
Indian blue peafowl (<i>Pavo cristatus</i>)	17	Ruffled feathers, one eye opacity, upper respiratory swelling, diarrhea, off feed, dullness, enteritis, gizzard dilatation, laziness and cornered, temperature, nasal discharge, open mouth, breathing, respiratory distress, upper respiratory swelling, coccidiosis, anorexia, weakness, congestion, infraorbital swelling
Demoiselle crane (<i>Anthropoides virgo</i>)	4	Coryza, lame, dull and depressed, swollen eyes
Emerald peafowl (<i>Pavo cristatus</i> <i>p.muticus</i>)	3	Roughed feathers, coryza, egg bound
Greater flamingo (<i>Phoenicopterus roseus</i>)	3	Egg-drop syndrome, coryza, sneezing
Golden pheasant (<i>Chrysolophus pictus</i>)	1	Infraorbital swelling
Green pheasant (<i>Phasianus versicolor</i>)	8	Dull and depressed, paresis, coryza, egg-bound disease, respiratory distress, weakness, diarrhea, lame
Grey ring-necked parakeet (<i>Psittacula krameri</i>)	1	Dull and depressed
Grey partridge (<i>Perdix perdix</i>)	2	Laziness and cornered
Java green peafowl (<i>Pavo muticus</i>)	2	Dull and depressed, rhinitis
Kalij pheasant (<i>Lophura leucomelanos</i>)	2	Congestion, coryza
Lady amherst pheasant (<i>Chrysolophus amherstiae</i>)	2	Sinusitis, chronic respiratory disease
Kalij pheasant (<i>Lophura leucomelanos</i>)	3	Dull and depressed, weakness, anorexia
Muscovy duck (<i>Cairina moschata</i>)	3	Coryza, diarrhea, enteritis
Pelican (<i>Pelecanus onocrotaphus</i>)	1	Nasal discharge
Pied peafowl (<i>Pavo cristatus</i>)	3	Dull and depressed, respiratory distress, rhinitis
Rose-ringed parakeet (<i>Psittacula krameri</i>)	4	Sinusitis, hyperthermia, dull, respiratory issue
Ring-necked pheasant (<i>Phasianus colchicus</i>)	13	Facial swelling, coryza, cyst over right eye region, respiratory distress, upper respiratory swelling, infraorbital swelling, lameness, weakness, chronic respiratory disease, dull and depressed, sneezing, abnormal breathing, corneal opacity
Silver pheasant (<i>Lophura nycthemera</i>)	3	Coryza, dull, lethargy

DISCUSSION

The current research was aimed to study the prevalence of diseases and other pathological conditions at selected zoos and wildlife parks. Lahore Zoo had the highest number of cases of diseases and other pathological

conditions studied in animals among all the selected captive breeding sites, which can be attributed to the fact that Lahore Zoological Gardens holds the highest number of species of animals and birds among all the selected captive breeding sites in this study.

In our study, infectious diseases were the most

common health concern in animals and other health issues included gastrointestinal, cardiovascular, and respiratory issues. In a similar study, a survey conducted on mortalities in captive animals revealed that the most frequent cause of death were infectious diseases and gastrointestinal issues (Scaglione *et al.*, 2019). A retrospective study on Zoo animals also concluded that the most common cause of

death was infectious diseases (Cigler *et al.*, 2020). Another study based on post-mortem reports of captive animals in a zoo revealed that the commonly diagnosed pathological conditions were gastrointestinal issues and respiratory diseases (Anga and Akpavie, 2002).

Table V. Causes of captive birds' mortality in selected study sites.

Species	Number of diseases/ Pathological conditions	Causes of mortality
Albino pheasant (<i>Crossoptilon crossoptilon</i>)	2	Heat stroke, salmonellosis
Alexandrine parakeet (<i>Psittacula eupatria</i>)	5	Chronic respiratory disease, salmonellosis, colibacillosis, enteritis, pulmonary edema
Bar headed goose (<i>Anser indicus</i>)	1	Ulcerative enteritis
Black partridge (<i>Melanoperdix niger</i>)	6	Chronic respiratory syndrome, colibacillosis, peritonitis, respiratory issue, septicemia, travelling stress
Black shouldered peafowl (<i>Pavo cristatus</i>)	29	Acute enteritis, anemia, bacterial infection, bronchopneumonia, coccidiosis, colibacillosis, congested heart failure, coryza, <i>E. coli</i> infection, egg-bound disease, enteric fever, enteritis, food toxicity, fowl typhoid, heart failure, heat stroke, hemorrhage on intestines, leucosis, mycotoxin, necrotic enteritis, nephritis, new castle disease, pasteurellosis, pneumonia, respiratory distress, respiratory issue, salmonellosis, septicemia, ulcerative enteritis
Black swan (<i>Cygnus atratus</i>)	4	Avian influenza, congested lungs, enteritis, typhoid
Blossom headed parakeet (<i>Psittacula roseata</i>)	1	Renal failure
Blue and gold macaw (<i>Ara ararauna</i>)	1	Colibacillosis
Grey partridge (<i>Perdix perdix</i>)	3	Enteritis, heart failure, heat stroke
Budgerigar (<i>Melopsittacus undulates</i>)	2	Enteritis, new castle disease
Cameo peafowl (<i>Pavo cristatus</i>)	2	Enteritis, pneumonia
Caroline duck (<i>Aix sponsa</i>)	1	Fowl typhoid
Chukar partridge (<i>Alectoris chukor</i>)	19	Bronchopneumonia, coccidiosis, colibacillosis, congested lungs, coryza, <i>E. coli</i> infection, enteritis, heat stress, heat stroke, hepatitis, nephritis, perihepatitis, respiratory failure, salmonellosis, septic yolk, septicemia, severe anemia, typhoid, ulcerative enteritis
Collard dove (<i>Streptopelia decaocto</i>)	1	Enteritis
Common duck (<i>Anas platyrhynchos</i>)	8	Ascites, avian influenza, enteritis, hemorrhagic enteritis, low immunity, nephritis, renal failure, respiratory failure
Common geese (<i>Anser anser domesticus</i>)	5	Avian influenza, food toxicity, liver toxicity, respiratory distress, ulcerative enteritis
Indian blue peafowl (<i>Pavo cristatus</i>)	21	Avian influenza, bacterial infection, chronic respiratory disorder, coccidiosis, colibacillosis, congested lungs, congestive heart failure, coryza, egg bound disease, endoparasites, enteritis, hemorrhagic enteritis, necrotic enteritis, new castle disease, peritonitis, respiratory distress, salmonellosis, ulcer in gizzard, uterine infection, fowl typhoid, heat stroke

Table continues on next page.....

Species	Number of diseases/ Pathological conditions	Causes of mortality
Demoiselle crane (<i>Anthropoides virgo</i>)	6	Enteritis, bronchitis, congested heart failure, nephritis, septicemia, hepatitis
White dove (<i>Streptopelia risoria</i>)	1	Suspected ulcerative enteritis
Eagle (<i>Aquila nipalensis</i>)	1	Travelling stress
Falcon (<i>Falco peregrinus peregrinator</i>)	1	Respiratory distress
Finch (Fringillidae)	7	Dehydration, enteritis, hepatitis, lung congestion, pneumonia, respiratory distress, ulcerative enteritis
Fisher bird (<i>Agapornis fischeri</i>)	2	Heat stroke, new castle disease, mycoplasma infection
Greater flamingo (<i>Phoenicopterus roseus</i>)	1	Mycoplasma infection
Golden pheasant (<i>Chrysolophus pictus</i>)	1	Liver intoxication
Green pheasant (<i>Phasianus versicolor</i>)	33	Lung failure, acute pneumonia, bronchopneumonia, cecal ulceration, peritonitis, chronic respiratory disease, coccidiosis, colibacillosis, congested enteritis, diarrhea, <i>E. coli</i> infection, enteritis, enteritis, food toxicity, gastrointestinal issue, heat stress, heat stroke, hemorrhagic enteritis, mycotoxicosis, nephritis, new castle disease, omphalitis, pneumonia, renal failure, respiratory distress, respiratory tract infection, salmonellosis, septicemia, suspected nephritis, suspected parasite infection, toxic material ingestion, tracheitis, ulcer in small intestine, ulcerative enteritis, primary congestion
Green winged macaw (<i>Ara chloropterus</i>)	1	Respiratory distress
Grey partridge (<i>Perdix perdix</i>)	4	Coryza, <i>E. coli</i> infection, enteritis, heat stroke
Grey pheasant (<i>Polyplectron bicalcaratum</i>)	3	Ascites, heart failure, suspected egg impaction
Guinea fowl (<i>Numida meleagris</i>)	9	Avian influenza, chronic respiratory disease, necrotic enteritis, nephritis, perihepatitis, pneumonia, respiratory distress, respiratory tract infection, salmonellosis
Java green peafowl (<i>Pavo muticus</i>)	2	Colibacilloses, influenza infection
Java sparrow (<i>Lonchura oryzivora</i>)	1	Bronchopneumonia
Lady amherst pheasant (<i>Chrysolophus amherstiae</i>)	1	Enteritis
Love bird (<i>Agapornis personatus</i>)	7	Coryza, heat stress, hemorrhagic enteritis, lung congestion, nephritis, pneumonia, septicemia
Mallard duck (<i>Anas platyrhynchos</i>)	5	Anemia, intestinal hemorrhage, necrotic enteritis, respiratory distress, ulcerative enteritis
Muscovy duck (<i>Cairina moschata</i>)	6	Ascites, <i>E. coli</i> infection, intestinal hemorrhage, liver intoxication, respiratory distress, ulcerative enteritis
Pelican (<i>Pelecanus onocrotaphus</i>)	5	Acute heart attack, avian influenza, bacterial growth in trachea, respiratory distress, <i>E. coli</i> infection
Pied peafowl (<i>Pavo cristatus</i>)	10	Avian influenza, bacterial infection, enteritis, heart failure, heat stress, necrotic enteritis, newcastle disease, ornithobacteriosis, salmonellosis, worm infestation
Quail (<i>Coturnix japonica</i>)	1	Nephritis
Red crested pochard (<i>Netta rufina</i>)	1	Enteritis
Red golden pheasant (<i>Chrysolophus pictus</i>)	2	Avitaminosis, food poisoning, enteritis

Table continues on next page.....

Species	Number of diseases/ Pathological conditions	Causes of mortality
Ring-necked pheasant (<i>Phasianus colchicus</i>)	33	Lung failure, newcastle virus, avian influenza, bronchitis, bronchopneumonia, chronic respiratory, disease, colibacillosis, coryza, crippled toe, diarrhea, <i>E. coli</i> infection, enteritis, fowl typhoid, fowl typhoid, heat stress, heat stroke, liver failure, low immunity, mycoplasma, mycotoxicosis, necrotic enteritis, nephritis, nervous disorder, perihepatitis, renal failure, respiratory failure, respiratory tract infection, salmonellosis, septicemia, severe anemia, traumatic gizzard, typhoid, yolk sac infection
Rose ringed parakeet (<i>Psittacula krameri</i>)	2	Colibacilloses, salmonellosis
Ruddy shell duck (<i>Tadorna ferruginea</i>)	1	Enteritis
Silver pheasant (<i>Lophura nycthemera</i>)	22	Chronic respiratory disease, coryza, egg bound disease, enteritis, food toxicity, heat stress, heat stroke, infectious bursal disease, liver enlargement and damage, mixed infection, nephritis, new castle disease, pneumonia, renal failure, respiratory tract infection, septic yolk, chronic respiratory disease, colibacillosis, respiratory distress, salmonellosis, ulcerative enteritis, yok sac infection
Teal duck (<i>Anas crecca</i>)	1	Traumatic gizzard
Turkey (<i>Meleagris gallopavo</i>)	10	Anemia, coryza, enteritis, heart failure, septic yolk, heat stress, liver failure, low immunity, lung congestion, suspected nephritis
White peafowl (<i>Pavo cristatus</i>)	13	Acute egg-bound disease, anorexia, ascites, avian influenza, bacterial infection, chronic respiratory disease, <i>E. coli</i> infection, enteritis, heat stress, liver intoxication, new castle disease, ornithobacteriosis, salmonellosis
White pheasant (<i>Crossoptilon crossoptilon</i>)	10	Anthraxis, ascites, colibacillosis, coryza, lung congestion, necrotic enteritis, renal failure, respiratory distress, ulcerative enteritis, tracheal congestion
White ring-necked pheasant (<i>Phasianus colchicus</i>)	3	Enteritis, hepatitis, respiratory distress
Yellow golden pheasant (<i>Chrysolophus pictus</i>)	3	Congested lungs, coryza, enteritis
Ostrich (<i>Struthio camelus</i>)	1	Cardiac arrest

The current study reported that cardiovascular issues accounted for 7% of the overall prevalence of health issues in animals. Similarly, cardiovascular issues in captive animals have also been reported in other studies especially in apes. A study concluded that cardiovascular issues were a leading cause of mortality in captive great apes in zoological institutions (Murray *et al.*, 2019) and in another research, cardiovascular issues were indicated to be a frequent cause of mortality in captive animals and the highest cause of mortality in captive chimpanzees (*Pan troglodytes*) (Laurence *et al.*, 2017).

Dystocia was the most common reproductive issue reported in our study. Dystocia has also been reported by other studies in other captive animals for instance in giraffe *Giraffa camelopardalis reticulata* (Yong *et al.*, 2009) and rhinoceros *Rhinoceros unicornis* (Schaftenaar *et al.*, 2011). Health conditions such as lameness, stress,

weakness, hypothermia, hyperthermia, dehydration, heat stroke, and anorexia constituted 23% of overall health conditions in animals. Conditions like starvation, general debility, and stress were also reported in captive animals in another study (Sharma *et al.*, 2014). As the temperature of surrounding environment has a significant impact on the health of captive animals, shade is an essential resource within the enclosure to protect animals from thermal discomfort in the summer months along with the availability of a water pool (Young *et al.*, 2013). Thus, conditions like heat stroke and heat stress can be prevented by taking these measures. Furthermore, shelter can also provide protection from extreme cold to captive animals.

Animals in captivity may suffer from a very wide range of infectious diseases, caused by bacteria, viruses, fungi, parasites, and other infective agents (Rees, 2011). In our study the most prevalent bacterial diseases in captive

animals were Pneumonia and tuberculosis. These results are similar to a study based on post-mortem record of captive ungulate species in Lahore Zoo, Lahore Wildlife Park and Jallo Wildlife Park which also showed in their results that pneumonia and tuberculosis were the most common bacterial diseases, responsible for 8.29% and 3.69% deaths in animals (Ali *et al.*, 2014). Zhao *et al.* (2021) also reported in their study that pneumonia was a serious threat in the captive breeding efforts for threatened species. While the prevalence of tuberculosis in captive animals was also mentioned in a study conducted at a zoological park in India (Hota *et al.*, 2020).

Other infectious bacterial diseases including anthrax, salmonella, tetanus, *E. coli*, typhoid and caseous lymphadenitis were also seen in captive animals. A study conducted in a zoological garden also reported *E. coli* in captive tortoise *Manouria emys phayrei* (Rajkhwa *et al.*, 2017). While among infectious diseases, infestations had a high prevalence of 20%, similarly, Naz *et al.* (2021) studied endoparasitic infestations in three captive breeding sites including Lahore Zoo, Safari park and Jallo wildlife park and reported the prevalence of various endoparasites including coccidia, cestodes, nematodes and trematodes coccidia. Another study on gastrointestinal parasites of captive animals in a zoo indicated an overall 62% prevalence rate of parasites among different groups of captive animals (Kolapo and Jegede, 2017).

In our study, non-bacterial infectious diseases also included feline panleukopenia, bronchopneumonia and trypanosomiasis. Feline panleukopenia is caused as a result of carnivore protoparvovirus 1 and even with the treatment, it is reported to have a significant mortality rate of 50-80% (Barrs, 2019). Studies conducted in Lahore Zoo reported a case of trypanosomiasis in a puma (*Felis concolor*) (Rashid *et al.*, 2017) trypanosoma infestation in brown tigers and white tigers (Khan *et al.*, 2015).

Non-infectious diseases in captive animals included hemorrhagic gastroenteritis. Another study also reported the prevalence of hemorrhagic gastroenteritis as a cause of death in captive leopard *Panthera pardus* (Moudgil and Singla, 2013). In our study, other non-infectious diseases included cancer and cancer related issues including tumor, skin cancer, and neoplasia. Similar to our results, a research based on necropsy reports of 26 captive felids in a zoo, also mentioned neoplasia as a significant cause of death in 28% of the studied necropsy reports (Owston *et al.*, 2008).

In birds, Safari Zoo Lahore had the highest prevalence of diseases and pathological conditions, which can be justified by the reason that this site has the second highest number of bird species and that too at one location, after Lahore Zoo.

Infectious diseases were the most common health

issue among birds (37%), and other common health concerns included gastrointestinal issues, respiratory issues, reproductive complications, and excretory system disorders. Similar to our results, a study carried out on captive birds also suggested that the common cause of mortality included infectious diseases such as new castle virus disease, gastrointestinal disorders like enteritis, heart and respiratory failure (Tariq *et al.*, 2019). Another study based on necropsy reports to investigate diseases in birds also reported cardiovascular issues among the most common health conditions (Bello *et al.*, 2017).

The most prevalent infectious diseases in birds in our study were salmonellosis and infectious coryza, which have been reported in captive birds by other studies as well. A research also reported the prevalence of *Salmonella* infection in 13 species of captive birds, and it was suggested that the prevalence rates significantly varied among different species (Allgayer *et al.*, 2008). In another study, infectious coryza was studied in 22 peafowls, in captivity which were suffering from respiratory tract infections and a high morbidity of 70% was seen (Adenkola *et al.*, 2016). While colibacillosis was also reported in birds, and can be caused entirely or partly by an avian pathogenic bacteria, *Escherichia coli*, (Nolan *et al.*, 2020) that has been studied extensively in poultry and farm birds (Díaz-Sánchez *et al.*, 2013).

Newcastle virus, avian influenza, and coccidiosis were also studied in birds. Newcastle virus in captive birds has been reported previously in many countries including Pakistan however, majority of studies reported that these infectious outbreaks occurred for short time periods and infected birds showed clinical symptoms like respiratory, enteric and neurological signs (Wajid *et al.*, 2017). A study based on the disease patterns in birds kept at a zoological garden in Nigeria also reported Newcastle and salmonellosis diseases in the captive birds (Emikpe *et al.*, 2016). Similarly, the prevalence of coccidiosis in captive peacocks, was reported in different captive breeding sites in Lahore including Lahore Zoo, Jallo park and Safari Park (Fiaz, 2013). Avian Influenza was also reported in captive birds in two safari parks and a zoo in Bangladesh (Hassan *et al.*, 2020).

In our study, parasite worm infestations were also reported in birds. Parasitic infestations have also been reported in many other studies in captive birds. A survey investigated the prevalence of gastrointestinal parasites in captive birds reported significant prevalence of various parasite species (Akram *et al.*, 2019). Our results revealed prevalence of necrotic enteritis among other gastrointestinal related infections. Similarly, one study on captive macaws *Ara ararauna* in a zoological garden also reported occurrence of necrotic enteritis in them (De Santi *et al.*, 2020).

Table VI. Recommendations for the improvement of healthcare system and facilities for captive animals and birds in selected study sites.

Problems	Site(s)	Recommendations
Absence of a permanent veterinary doctor	Bansra Gali Murree Wildlife Park	Provision of at least one permanent veterinary doctor .
Cleanliness	All study sites	The punctuality and quality of cleanliness should be improved by cleaning the enclosures at least twice a day with the help of disinfectants to prevent infections and to remove unpleasant smell.
Inappropriate/Insufficient size of enclosure/cage sizes	All study sites	Appropriate enclosure/cage sizes meeting international standards should be provided to all animals and birds. Guidelines by authorities such as Association of Zoos and Aquariums (AZA), International Wildlife Rehabilitation Council (IWRC) and National Wildlife Rehabilitators Association's (NWRA) may be used in this regard.
Deliberate feeding by public/visitors	Lahore Zoological Gardens, Gatwala Wildlife Park, Bahawalpur Zoo	Strict control for deliberate feeding by public should be adapted and all such activities should be monitored and prohibited.
Untrained animal keepers	All sites	Recruitment of qualified and trained animal keepers along with regular training and workshops on animal handling.
Unavailability of inbuilt laboratory for Post-Mortem Examination	All study sites except Vehari Wildlife Park	Wherever possible, captive breeding facilities should have their own laboratory for post-mortem investigations for timely investigation of causes of mortalities.

CONCLUSIONS

In conclusion, prevalence of diseases and pathological conditions in both captive animals and birds are a major issue for captive breeding facilities. A significant number of different diseases and pathological conditions in animals and birds came across with this current study. In animals, the highest number of causes of morbidity and mortality were noted in Mouflon Sheep, Hog Deer and Spotted Deer and apart from general health conditions, the most common issue in animals was infectious diseases 26%, while other major health concerns included gastrointestinal, cardiovascular, reproductive, respiratory, and generalized issues. The most prevalent infectious diseases were pneumonia, tuberculosis, and infestations. In birds, the highest number of causes of morbidity and mortality were noted in Ring-necked Pheasant, Black Shouldered Peafowl and Green Pheasant, and in birds, infectious diseases contributed 37%, while other significant pathological conditions and diseases included gastrointestinal issues, respiratory complications, blood related disorders, reproductive complications, and generalized conditions. Among infectious diseases in birds, salmonellosis and infectious coryza were the most prevalent, followed by colibacillosis.

RECOMMENDATIONS

The overall health care and treatment facilities in most

of the selected captive breeding sites were unsatisfactory, while the record of diseases, pathological conditions and treatment of animals were properly maintained. Based on general observations, some issues were noted, and recommendations have been given to overcome these in order to improve the overall healthcare system of captive animals and birds in the selected study sites (Table VI). Further, the prevalence of diseases and pathological conditions can be reduced by adopting scientific management as per directions given by the international authorities such as Association of Zoos and Aquariums and European Association of Zoos and Aquaria for the captive breeding facilities.

The prevalence of diseases and pathological conditions can be reduced by measures such as regular monitoring for early detection of diseases, prohibition of deliberate feeding by visitors, provision of sufficient enclosure sizes, and practicing adequate cleanliness and by following the guidelines for healthcare of animals given by international authorities.

Supplementary material

There is supplementary material associated with this article. Access the material online at: <https://dx.doi.org/10.17582/journal.pjz/20210805120803>

Statement of conflict of interest

The authors have declared no conflict of interest.

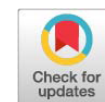
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Online First Article



Supplementary Material

Causes of Morbidity and Mortality in Wild Animals and Birds at Captive Breeding Facilities of Punjab, Pakistan

Zahra Hussain, Zulfiqar Ali* and Rida Ahmad

Environmental Health and Wildlife Laboratory, Institute of Zoology, University of the Punjab, Lahore, Pakistan

Supplementary Table S1. Diseases and pathological conditions in animals.

Sr. No.	Disease/ Condition/ Clinical symptom	Type	Baha-walpur zoo	Bansra Gali Murree wildlife park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Su-hanara national park	Vehari wild-life park
			1	2	3	4	5	6	7	8	9	10
1	Abnormal behavior	Condition		1								
2	Acidosis	Condition				1						
3	Allergy	Condition							2			
4	Alopecia	Condition	1	1		2						
5	Anemia	Condition							2	2		
6	Anorexia	Condition		1			1		2			1
7	Ascites	Condition							6		1	
8	Anthrax	Disease				1						
9	Atresia ani	Condition								1		
10	Bacterial infection	Disease			1							1
11	Birth complication	Condition										
12	Bronchopneumonia	Disease				1		1		1		
13	Bronchitis	Disease										1
14	Bradycardia	Condition				1						
15	Breathing difficulty	Condition									1	
16	Bloody Diarrhea	Condition								1		
17	Captivity stress	Condition										
18	Cardiac arrest	Condition				3			2	2		1
19	Cardiovascular failure	Condition								1		
20	Hepatic failure	Condition							1			
21	Chronic wasting disease	Disease				1						

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* Corresponding author: zali.zool@pu.edu.pk
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Sr. No.	Disease/ Condition/ Clinical symptom	Type	Baha-walpur zoo	Bansra Gali Murree wildlife park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Su-hanara national park	Vehari wild-life park
22	Coccidiosis	Disease							1			
23	Choking	Condition									1	
24	Coryza	Disease									2	
25	Cough	Condition							1			
26	Dehydration	Condition							3			
27	Dermatitis	Condition					1					
28	Diarrhea	Condition			3	1	1	3	16	3	1	1
29	Dull and Depressed	Condition	2	1	1	1			2	1	2	2
30	Dystocia	Condition	1		1		1	1	2		5	1
31	<i>E. coli</i> infection	Disease							1			
32	Ectoparasites and endoparasites	Disease							4			
33	Enteritis	Condition			1				6	2	11	
34	Typhoid	Disease		1								
35	Epistaxis	Condition								1		
36	Emaciation	Condition		1		1						
37	Eye infection	Condition										1
38	Feline panleukopenia	Disease							3			
39	Foot rot	Disease		1								
40	Gastroenteritis	Condition							4	1		
41	Gastrointestinal Disorder	Condition	1	1			1					1
42	Gastrointestinal tract compaction	Condition							1			
43	Heart Failure	Condition	3	2	1		1	2		1	9	4
44	Heat stress	Condition					3				1	
45	Heat stroke	Condition									3	
46	Hydatid Cyst	Condition			2							
47	Hemorrhagic gastro-enteritis	Disease							5	2		
48	Hepatitis	Condition							1			
49	Hygroma	Condition	1									
50	Hyper excitation	Condition							1			
51	Hyperkeratosis	Condition								1		
52	Hypothermia	Condition	1	1					1	1	1	1
53	Hyperthermia	Condition	1						4		1	
54	Hypovolemic shock	Condition				1		1				
55	Indigestion	Condition	2				1					
56	Infectious myositis	Disease							1			
57	Intestinal strangulation	Condition	1									
58	Lactic Acidosis	Disease					1					
59	Lameness	Condition	1	1		1	1		9	1	1	
60	Lethargic	Condition								2		

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Sr. No.	Disease/ Condition/ Clinical symptom	Type	Bahawalpur zoo	Bansra Gali Murree wildlife park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Suhanara national park	Vehari wild-life park
61	Liver fluke infestation	Disease						1				
62	Lymphadenitis	Disease							2			
63	Malaria	Disease							1			
64	Myasis	Disease								2	7	
65	Nasal discharge	Condition		1					1		1	
66	Nervous disorder	Condition				2						
67	Neoplasia	Disease								1		
68	Necrosis	Condition							1			
69	Paralysis	Condition	1									
70	Peritonitis	Condition				1	1		1	1		
71	Pneumonia	Disease	3		2	4		2	10	6	20	3
72	Pulmonary congestion	Condition				1			3	1		
73	Pulmonary edema	Condition								1		
74	Protozoal Infection	Disease				1		1	2			
75	Rectal prolapse	Condition							1			
76	Ruminal impaction	Condition								1		
77	Respiratory distress	Condition	1						4	1		
78	Respiratory failure	Condition					1		3	5	3	1
79	Respiratory infection	Condition							1			
80	Restlessness	Condition							1			
81	Round worm infestation	Disease							1			
82	Salmonella infection	Disease							1			
83	Shivering	Condition									1	
84	Septic shock	Condition							1			
85	Septicemia	Condition					3		3	4	1	
86	Spinal cord compression	Condition							1			
87	Skin infection	Condition								1		
88	Skin Allergy	Condition							5			
89	Skin Cancer	Disease									1	
90	Swelling	Condition	1						2			
91	Tetanus	Disease				1						
92	Tympanites	Condition								1		
93	Toxemia	Condition			2				1	1		
94	Trypanosomiasis	Disease						1	1			
95	Tuberculosis	Disease	1						3	4	1	1
96	Tumor	Disease								1		1
97	Gastroenteritis	Condition							1			
98	Off feed	Condition		2								
99	Urine retention	Condition				1						
100	Vomiting	Condition							1	1		
101	Weakness	Condition	3	3	5	1			7	1		3
102	Worm infestation	Disease					3		2			1

Supplementary Table S2. Disease and pathological conditions in birds.

Sr. No.	Disease/ condition/ Clinical symptom	Type	Baha-walpur zoo	Bansra Gali murree wildlife Park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Su-hanara national park	Vehari wildlife park
1	Anemia	Condition	5						2			
2	Allergy	Condition							1			
3	Abnormal breathing	Condition	2									
4	Anorexia	Condition		1		2	1			2		1
5	Anthraxis	Disease							1			
6	Ascites	Condition		1					4			1
7	Avitaminosis	Disease							1			
8	Avian influenza	Disease							3	12		
9	Avian tuberculosis	Disease									1	
10	Bacterial infection	Disease							1	4		
11	Histomoniasis	Disease										
12	Bronchopneumonia	Disease						2	10			
13	Bronchitis	Disease	2									
14	Bursal disease	Disease		1								
15	Caseous necrosis	Condition	1									
16	Chronic respiratory disorder	Disease		4	8		3		1	1		2
17	Coccidiosis	Disease	3				2	1	5	1	3	
18	Colibacillosis	Disease				1	1	1	13	13		
19	Congestion	Condition						2				
20	Coughing	Condition				2						
21	Congested lungs	Condition		1					3			
22	Coryza	Disease	1	4	1	4	4	4	9	2	4	1
23	Crippled toe	Condition							1			
24	Cyst	Condition						1				
25	Dull and depressed	Condition	13			5	12	3	31	2		9
26	Dehydration	Condition							1			
27	Diarrhea	Condition	1		1	6	1		1			1
28	<i>E. coli</i> infection	Disease					2			12		
29	Egg bound	Condition	4	2	1		2	2				1
30	Egg drop syndrome	Disease		1								
31	Endoparasites	Disease							1	1		
32	Enteritis	Condition	8	4	1	2	7	5	25	11	3	6
33	Eye opacity	Condition					1	1				
34	Food poisoning	Disease		1				1	4			
35	Fever	Condition										1
36	Gastroenteritis	Condition								1	3	1
37	Fowl typhoid	Disease	5			1					17	

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Sr. No.	Disease/ condition/ Clinical symptom	Type	Baha-walpur zoo	Bansra Gali murree wildlife Park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Su-hanara national park	Vehari wildlife park
38	Gasping	Condition				2		1				
39	Heart failure	Condition	7	1			4					
40	Hypovolemic shock	Condition				1						
41	Heart attack	Condition										1
42	Heat stroke	Condition	12			1	2			2		
43	Heat stress	Condition						1	11	1		
44	Hepatitis	Condition							2	1		1
45	Intestinal hemorrhage	Condition							3			
46	Isolated	Condition	4									
47	Hemorrhagic enteritis	Condition				1	1		2			
48	Hyperthermia	Condition				4						
49	Lameness	Condition			2	1			23	1		
50	Leucosis	Disease									1	
51	Lethargy	Condition	9				1		1			
52	Liver failure	Condition							1	1		
53	Low immunity	Condition							3			
54	Liver intoxicification	Condition							5			
56	Limping	Condition						1				
57	Liver enlargement and damage	Condition		1								
58	Lung congestion	Condition							4			
59	Mycoplasma infection	Disease	1						1			
60	Mycotoxiosis	Disease						2		2		
61	Nasal discharge	Condition					1	1				
62	Nephritis	Condition						2	15			
63	Newcastle disease	Disease		1	23				2	1		
64	Necrotic enteritis	Disease	3						2	6		
65	Nervous disorder	Condition				1						
66	Off feed	Condition				1			2			
67	Omphalitis	Disease							4			
68	Ornithobacteriosis	Disease					2					
69	Paresis	Condition						1				
70	Perihepatitis	Condition								3		
71	Pasteurellosis	Disease							1			
72	Peritonitis	Condition				1				2		
73	Pneumonia	Disease						1	6	4		3
74	Recumbency	Condition					1					

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Sr. No.	Disease/ condition/ Clinical symptom	Type	Baha-walpur zoo	Bansra Gali murree wildlife Park	Pirowal wildlife park	Changa Manga wildlife park	Gatwala wildlife park	Jallo wildlife park	Lahore zoo-logical garden	Lahore zoo safari	Lal Su-hanara national park	Vehari wildlife park
75	Pulmonary congestion	Condition								1		
76	Pulmonary edema	Condition								1		
77	Renal failure	Condition							7	1		
78	Respiratory failure	Condition								4		
79	Respiratory tract infection	Condition				5						
80	Respiratory distress	Condition				1	2	7	16	10		1
81	Respiratory issue	Condition							4			1
82	Ruffled feather	Condition					1					
83	Salmonellosis	Disease	10			1	3	2	1	11	5	1
84	Sneezing	Condition		3								
85	Stress	Condition						1				
86	Septic yolk	Condition						1	2			
87	Septicemia	Condition					3		4	4		
88	Sinusitis	Condition			2	1		3		1		
89	Spraddle leg	Condition					1					
90	Swelling	Condition		3				2			1	
91	Travelling stress	Condition					2					
92	Traumatic gizzard	Condition								2		
93	Toxic material ingestion	Condition										1
94	Ulcerative enteritis	Disease				1			13			
95	Upper respiratory swelling	Condition						3				
96	Ulcers	Condition				1	1					
97	Uterine impaction	Condition		1								
98	Weakness	Condition	3	1	1			2	2	1		3
99	Worm infestation	Disease							1			