AVIAN ELECTROCUTION AND POWER LINE COLLISION IN PUTALIBAZAR MUNICIPALITY OF SYANGJA DISTRICT, NEPAL

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Batch: 2075

A thesis submitted in partial fulfilment of the requirements for the award of the Degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

August 2022

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude and indebtedness to my thesis supervisor, Associate Professor Dr. Hari Prasad Sharma, Central Department of Zoology, for his continuous guidance, immense help, valuable suggestions and knowledge regarding the subject matter. This thesis would not have taken its present shape and quality without his untiring efforts.

I want to thank Professor Dr. Tej Bahadur Thapa, Head of Department of the Central Department of Zoology for providing administrative supports. I am highly obliged and extend my thanks to all of my respected teaching and non-teaching staffs of the Central Department of Zoology, for their kind support, guidance, and feedback on my research project and other academic courses during my study at the department.

I would like to thank my brothers Mr. Saujan Hamal and Mr. Sugan Hamal for their constant assistance throughout the field data and sample collection for my research work.

I would like to thank the respondents of questionnaire survey for their interest, participation and assistance in my work. I acknowledge my gratitude to my friends Sweety Nakarmi, Sapana Chand, Neelam Mahata, Sharmila Tamang, Sandeep Regmi, Hari Sharan Giri, Sovit Sapkota and Kuber Bahadur Singh for their encouragement, interest, support and advice in successful completion of the dissertation.

I am indebted and express my sincere gratitude to my guardians, who supported economically and encouraged me throughout the research period. I am very grateful to all the people who encouraged me during the study period and all my friends for their direct or indirect help in completing this work.

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ABSTRACT

Avian fauna refers to the different species of flying as well as flightless birds. A well-developed adaptation feature of avian species is that they have flight in short and long distances, and perch at different objects including twigs and power line. In spite of these adaptations, avian species are suffered from various threats due to different environmental and anthropogenic factors which may cause significant decline in their population. Among the various anthropogenic factors, the power lines become threats to the avian species mainly due to electrocution and power line collisions. However, the data on this threat on avian species are scarce, therefore, this study collected data on the highly affected bird species due to the power lines in the Putalibazar Municipality of Syangja district from November 2021 to May 2022 along the distribution line which runs through the agricultural land or forest or settlement area or river basin. Direct observation and questionnaire methods were used to collect data on power lines related avian mortality under 10 m circular radius around the poles in every 300 m interval. For the collision data, the carcasses of birds were sampled along the distribution line. Out of 43 avian victims, 26 were found dead due to electrocution in 15% (n = 18) of the plots. Among the affected avian species the House Crow *(Corvus splendens)* and Rock Pigeon *(Columba livia)* were the major victims. Seventeen individuals of six different species were recorded for collision out of which Common Myna *(Acridotheres tristis)* and House Swift *(Apus nipalensis)* were the major victims. The bird’s abundance, distance to agricultural lands and settlement were found to have a significant association with the power lines related avian mortality. Based on these data the policy makers can develop avian friendly power lines infrastructures and planning for their long term conservation.

1. INTRODUCTION

1.1 Background

Power transmission lines are the high-tension wires carrying electricity of a magnitude greater than 60 Kilovolts from the power plant to substations, whereas the distribution lines are the high-tension wires carrying electricity of a magnitude between one Kilovolt and 60 Kilovolts (APLIC 2012). Because of their above ground distribution, the flight of avian faunas, such as birds and bats are affected, and suffered from electrocution and line collisions. For example, 12 to 64 million birds were died at USA power lines due to power line collisions and electrocution annually (Loss et al. 2014). Similarly, 10 to 41 million birds were died by power line collisions annually in Canada (APLIC 2006). Electrocution occurs primarily at distribution lines and collisions occur at both distribution lines and transmission lines (Lehman et al. 2007, Dwyer et al. 2016). Power line collisions occur when birds fly into wires, whereas electrocutions occur at poles when a bird completes a circuit by touching two energized parts or an energized part and a grounded part (Real et al. 2001). Transmission lines have relatively large separations between insulators and air gaps > 1.5 m around energized parts, resulting in a low number of electrocutions worldwide (APLIC 2006, Ferrer et al. 2012).

Power line collision is one of the major but less emphasized anthropogenic factors for bird's mortality (Cornwall and Hochbaum 1971, Scott et al. 1972, McNeil et al. 1985). The lack of familiarity of migrant and over wintering birds with the location of obstacles leads to their higher mortality compared to that of the resident individuals (Alonso et al. 1994). The long lived species with a low reproductive rate are likely to be affected even by the low collision rates and have a lower ability to compensate by increasing productivity (Newton 1998). Night migrants and birds with heavy body and short wings are facing threats from collision (Bevanger 1998), whereas the larger birds are more likely to be electrocuted than the smaller ones (Bevanger 1998, Janss 2000). Collision susceptibility is determined by morphology and physical flight, which includes flight behavior, flocking degree, and vision differences (Bevanger 1994,1998, Janss 2000). Raptors are at high risk of electrocution in areas with high pole density, prey abundance, and fewer natural perches (Perez-Garcia et al. 2011). Avian species with naturally restricted ranges are threatened with extinction if they are susceptible to electrocution and collision risks (Berkunsky et al. 2017). Avian species with delayed maturity, low fertility rates, and smaller population sizes are severely affected by the electrocution and collision fatalities (Eccleston and Harness 2018, De Pascalis et al. 2020, Slater et al. 2020).

Underground cabling of the low and medium-voltage power lines is quite common in most of the developed countries, including Belgium, Germany, Norway, the Netherlands, and the USA, which is a boon to the bird's population with no any risks of collision and electrocution (Haas 2005). Although, the underground cabling is technically feasible, the costs of installing it can be 4–10 times higher than the construction of traditional overhead lines. In addition, the transmission lines are problematic because their burying entails greater technical and legal challenges to ensure low levels of electromagnetic field at the surface and consequently much higher costs (Raab et al. 2012). Careful route planning is regarded as one of the most effective ways to mitigate bird collisions with overhead power lines (D'Amico et al. 2018). The attachment of markers onto the power lines in the form of plates, spirals, flappers, swivels or spheres to increase their visibility has been by far the most common mitigation measure applied to reduce bird collisions with power lines (Barrientos et al. 2011, APLIC 2012). However, the detail information on the effects of distribution lines on avian species in Nepal is little known. Therefore, the study aims to provide the baseline data on the effects of distribution lines, which can be used for infrastructure development management plans.

1.2 Objective

1.2.1 General Objective

The overall objective of this field based research was to identify the effect of distribution lines on avian fauna in Putalibazar Municipality of Syangja district, Nepal.

1.2.2. Specific Objectives

i. To identify the highly affected avian species in the Putalibazar Municipality due to power line collisions and electrocution.
ii. To analyze the contributing factors for the power line related mortality of the avian species in Putalibazar Municipality of Syangja district.

1.3 Justification of Study

Nepal lies in the Himalayan belt to the Gangetic Plain, so it is one of the major migratory routes of the birds of higher altitudes and unmanaged transmission and distribution lines along such route seem to cause many fatalities in those migrating flocks. But there has been a very little study on the impacts of power distribution lines on avian fauna in the context of Nepal. There is no reliable data in this field due to lack of research, study, and policy in proper avifauna management. It is in front of our eyes that Nepal has very unmanaged authority of electricity and has little concern about the impacts of these unmanaged distribution lines on biodiversity level. Proper financial management is also lacking in the sector of infrastructure development. This is one of the reasons for carelessness in these areas. Besides, there is a significant research gap and lack of high-quality data in order to provide a thorough understanding of avifauna fatalities caused by distribution lines. This study aims to provide baseline data about the impacts on avifauna caused by distribution lines. This will help concerned bodies to make proper policies and plans in order to ensure the safety and proper conservation of avifauna in Nepal. So, the study is beneficial to conserve the avian population by analyzing the impacts of power distribution lines on them.

2. LITERATURE REVIEW

2.1 Vulnerability of avian fauna with power lines

The flight direction change and aborted flight are common reactions of birds approaching a power line (Faanes 1987). The greater mortality event of birds often occurs during the peak migration period, which might be due to the lack of familiarity of the migrants to the new location of obstacles (Crawford and Engstrom 2001). The long-term capture-recapture program on Bonelli's Eagle *(Aquila fasciata)* between 1990 and 2009 was performed by combining re-sightings of live and recovery of dead birds. It estimated that the survival probability of all age classes of Bonelli's Eagle was increased after supply of the insulation of dangerous power lines. The overall increase in survival due to power line insulation led to a sharp increase in predicted population growth rates from 0.82 to 0.98 (Chevallier et al. 2015). The birds that move regularly on a daily basis between their nesting sites and foraging sites are at a higher risk of colliding with electric wires (Pigniczki et al. 2019). Different bird species construct their nests on power lines, for example, 88.5% nest of Long-tailed Broadbills *(Psarisomus dalhousiae)* were on power lines, and their nest-site selection is determined by predation and food availability. These birds build their nest on power lines as an anti-predatory strategy (Zhou et al. 2020).

2. 2 Seasonal influence on avian mortality

Migratory and breeding seasons account for higher power line related avian mortality rate due to the increased number of birds in the study area (Lasch et al. 2010). Raptors, corvids, and storks are susceptible to get the electrocution during the breeding and migratory seasons due to lack of awareness about the landscapes and the related obstacles (Demerdzhiev 2014). Power line victims occur greatly in the late summer during the fledging and post fledging periods (Lehman et al. 2007, Lasch et al. 2010). Migration birds tend to fly at lower attitudes in poor weather conditions, which risk them with power line collision (Martin and Shaw 2010).

2.3 Habitat influence on avian mortality

Habitat type around power lines has been identified as an important indicator of electrocution risk (Janss and Ferrer 2001, Mañosa 2001). Species breeding in open habitats like wetlands, grasslands, etc. are more prone to electrocution because these habitats provide less nesting sites and natural perches (Lehman et al. 2007, Tintó et al.

2010). The raptors possess high risk of electrocution in undisturbed areas and during the breeding season due to the dispersal of juveniles and migratory movements (Lasch et al. 2010). The highest risk of electrocution and power line collisions is seen in undisturbed and open grasslands and during migratory seasons (Demerdzhiev 2014). The highest number of bird's collision seen below power lines crossing wetlands stresses the fact that the activity patterns of the scavenger influence the carcass disappearance rate which is higher in open farmland since the carcasses can be easily removed by the avian predators (Costantini et al. 2016). Prey availability in the given habitat directly influences the population of the predator birds, which ultimately increases the avian electrocution risks (Dixon et al. 2017). Avian electrocution and power line collisions are mainly driven by the surrounding habitat type and the electric fittings of the power lines (Hernández- Lambraño et al. 2018, Kolnegari et al. 2020).

2.4 Morphological and behavioral influence on avian mortality

Birds with low aspect ratio (i.e., short wings and short tails) are prone to power line collisions due to their swift maneuverability, whereas the birds with high aspect ratio (i.e., large wings and large tails) are more prone towards electrocution (Janss 2000). The collision and the electrocution events in avian fauna depend on the wing morphology of the species in which collision victims are poor fliers and the electrocution victims are birds of prey, ravens, and thermal soarers (Janss 2000). The avian species that build large communal nests are likely to face the electrocution and power outages (Burgio et al. 2014). Avian species flying in flocks are highly susceptible to electrocution risks (Galmes et al. 2018).

2.5 Electric fittings on avian mortality

Pylon's design and pole types have significant effect on bird's electrocution (Ferrer et al. 1991, Mañosa 2001, Demerdzhiev et al. 2009). Lack of wire markings and unsafe extant infrastructures induce greater collision and electrocution risks in avian fauna (Boshoff et al. 2011, Garcia-del-Rey and Rodriguez-Lorenzo 2011). The power lines of magnitude ≥ 66 kVs are less problematic than those of magnitude ≤ 33 kVs for avian mortality (Harness et al. 2013). Poles supporting jumpers and low center pins possess greater electrocution risks (Harness et al. 2013). Higher rates of outages are recorded for the orders Corvidiformes and Accipitriformes in sites of power lines using pin insulators and transformers (Kolnegari et al. 2020). Cross arm configuration of the electric poles possesses greater electrocution risks in raptors (Sarasola et al. 2020) and corvids (Orihuela-Torres et al. 2021). The line marking devices like bird flappers and bird's flight diverters significantly reduce the bird's collision risks (Shaw et al. 2021).

3. MATERIALS AND METHODS

3.1 Study Area

Putalibazar Municipality is one of five municipality of Syangja district, covering an area of 147.21 km^2 and extending from 28°03′18″N to 28°08′44″N and 83°47′30″E to 83°54′34″E, with the total population of 44,876 individual according the census of 2011. This municipality is divided into 14 wards. The elevation of this municipality is 836 m from sea level. This urban municipality came into existence in 1997 and restructured on 12 March 2017. Kali Gandaki "A" and Andhikhola hydropower stations are located in Syangja district. The actual field of study was along the distribution lines located in Putalibazar municipality, which extends through the settlement zones, highways, agricultural land, river basins, and the forest. Eight out of 14 wards were covered during the study which included ward number 1, 2, 3, 4, 10, 11, 13, and 14.

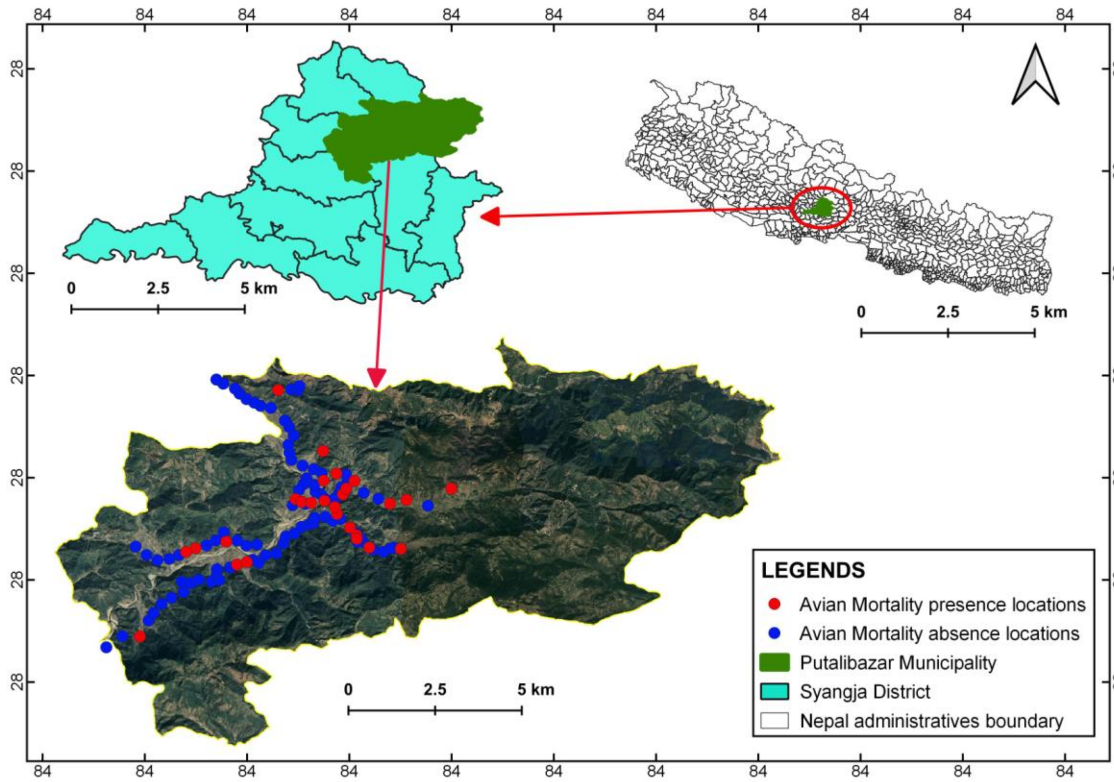

Figure 1: Avian Mortality location due to power lines collision and electrocution in Putalibazar Municipality from November 2021 to May 2022

3.1.1 Flora and Fauna

The distribution of wildlife in the study site is not uniform and depends upon habitat type, topographic features and human influences. Sal (*Shorea robusta*), Pine *(Pinus roxburgii),* Khair *(Senegalia catechu),* Katus *(Castanopsis indica),* and mixed hardwood forest are the major vegetation types of the study area. The primary crops grown in this region include paddy, maize, wheat, millet, pulses, and potatoes. Fruit trees include citrus, banana, guava, jackfruit, and peach. The Kalij Pheasant *(Lophura leucomelanos*), Red Junglefowl *(Gallus gallus)*, Cattle Egret *(Bubulcus ibis*), House Crow *(Corvus splendens)*, Common Myna *(Acridotheres tristis)*, etc. are the major birds species found in this region.

3.2 Materials

- GPS: Garmin Etrex 10: Location points
- Binocular: Cason 8×40 mm: Bird observation
- Spherical Densiometer: Forest canopy cover
- Camera: Nikon B3400
- Android Mobile: Samsung Galaxy J5 (2016)
- Data Collection Sheets and Questionnaire
- Field Guide Book: Birds of Nepal (Grimmett et al. 2016)

3.3 Methods

During this study, both secondary and primary data were collected. Secondary data on voltage types, such as low (11kV: having only one disc insulator per phase) and high (33kV: having three disc insulators per phase), distribution lines, and the number of electricity outages due to avian electrocution or collision events were also collected from the District Electricity Authority, Syangja. The primary data on the bird distribution, the number of birds killed due to electrocution, and collision were collected through field visits. At first, the preliminary survey was conducted from 10 October to 12 October 2021 to identify the routes of distribution lines in Putalibazar municipality of Syangja district. The data collection was conducted from 8 November 2021 to 12 May 2022. Altogether, four visits were conducted. A total of 30.6 km from 117 sites were used for data collection. Among these, a low voltage distribution line, i.e., 11 kV covered 28 study sites. High voltage distribution line, i.e., 33 kV covered 89 study sites. 48 sites fell within agricultural land, 29 in forest, 25 in settlement, and 15 sites along a river basin.

3.3.1 Bird Observation and Habitat Survey

A total of seven segments of low voltage distribution lines and eight segments of high voltage distribution lines with an average length of 900 m (648.07 m SD) and 3,037.5 m (1752.5 m SD) respectively, were identified in the study area based on the division junction. The distance between two consecutive power poles, i.e., the span length is 50 m for distribution lines ≤ 33 kV (NEA 2022). Therefore, along the distribution line, a circular plot of 10 m radius was established at every 6^{th} pole with an interval of 300 m between two plots. In each plot, the number of bird species, their total number, presence of bird nests, number of trees, forest canopy cover, and the habitat type were recorded. Before bird observation, five minutes were spent in each plot to make the area quiet with no disturbances due to the presence of the observer. The bird species and numbers that fell within the circular quadrate were recorded at every two-minute interval for 10 minutes. The highest number of every bird species for 10 minutes was taken for data analysis. The study was conducted from 6:00 am to 11:00 am. The birds were observed using the Cason 8×40 mm binocular and identified using the field guide book of birds (Grimmett et al. 2016).

In addition, the bird carcasses found within plot due to electrocution were recorded. The number of carcasses was also recorded along transects. If the bird carcasses were recorded, the plot was established and all variables were recorded in each plot.

The number of trees in each plot was recorded if the height of the tree was > 2 m tall. The forest canopy cover in each plot was measured from the center of each plot using a spherical densiometer. Habitat types such as agricultural land, forest, river basin, and settlement were recorded for each plot. The other predictive variables such as the nearest distance to agricultural land, forest, settlement, and water source were measured with meter tape. The distance > 200 m was measured using GIS.

In the study area, a questionnaire survey was performed with local people living nearest to the plot. A questionnaire was taken from altogether 42 local people, at least 5 people from each ward, of active age group 15 – 60 years to know whether they had knowledge on avian electrocution or collisions near to their distribution lines in the last six months.

Data on the time of avian electrocution or collisions, species, and their numbers were also noted.

3.3.2 Data Analysis

Ecological analyses Shannon Weiner diversity index (H') and evenness index (J) were calculated from the collected data.

Shannon − Weiner diversity index

Shannon – Weiner index was used to calculate avian diversity because it assumes all the species are represented in the sample.

$$H' = -\Sigma(p_i)\ln(p_i)$$

Where H'= Index of species diversity

$p_{i=}$ the proportion of individuals in the i^{th} species= n_i/N

n_i= Importance value for each species (number of individuals)

N= Total importance value (total number of individuals)

Pielou's Evenness index

Pielou's Evenness Index was used to calculate whether species were distributed evenly across different habitat types.

$$J = H'/\ln(S)$$

Where, H'= Shannon-Weiner's diversity index

S= Species richness (total number of species)

Generalized Linear Model (GLM) with binomial distribution was used to identify the factors affecting the avian electrocution and power-line collisions. Factors such as nearest distance to agricultural land, forest, settlement, and water source along with voltage, forest canopy cover, trees presence, and bird abundance were used for data analysis. Before conducting GLMs, correlation analyses were performed between each predictor variables to exclude those variables that were strongly correlated with $|r| > 0.7$ in the same model (Libal et al. 2011). In correlation analyses, trees count and forest canopy cover were highly correlated (| r | = 0.76). Therefore, trees count was excluded from the analysis.

Models were ranked using the Akaike Information Criterion adjusted for small samples (AICc) (Brunham and Anderson 2002) and Akaike model weights to estimate the relative strength of evidence for each model. Model averaging was done using all models within 4 AICc of the top model to estimate 95% confidence intervals for each variable and accepted statistical significance at $\alpha = 0.05$. All analyses were performed in R program (R Core Team 2019).

4. RESULTS

4.1 Birds Abundance and Diversity

Altogether, 853 individuals of 19 different species of 14 families belonging to nine orders were recorded along the distribution line in the study area (Appendix 1). Eight species were from order Passeriformes. Two species were recorded from each order Columbiformes, Pelecaniformes, and Accipitriformes. Psittaciformes, Caprimulgiformes, Galliformes, Cuculiformes, and Coraciformes contributed for one species each (Figure 2; Appendix 2).

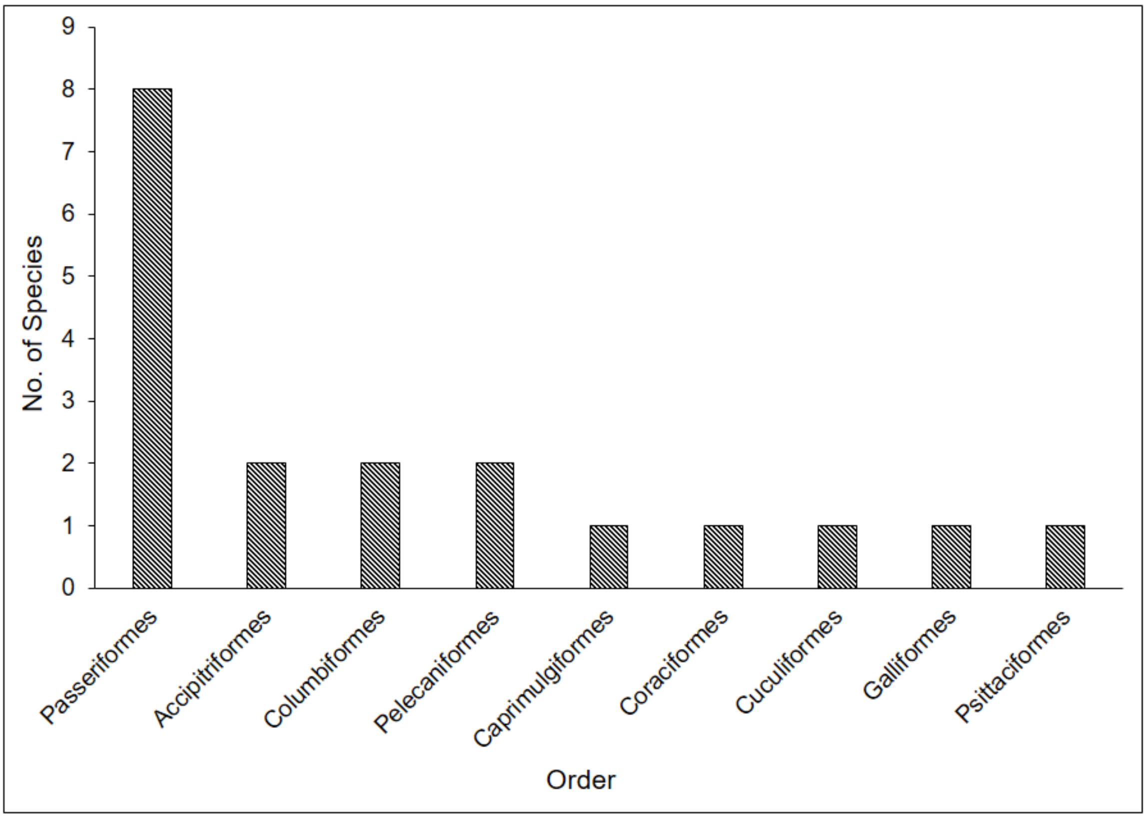

Figure 2: Number of Avian Species with their Orders in Putalibazar Municipality from November 2021 to May 2022

The overall Shannon − Wiener's diversity index (H') and Pielou's evenness index (J) of the avian species for the total study sites were found to be 2.372 and 0.805 respectively (Table 1). The agricultural land had the highest avian diversity and evenness index followed by the settlement area, the forest, and the river basin (Table 1). The diversity and the evenness indices among the habitat type of the avian species varied marginally.

Table 1:Diversity and Evenness indices according to habitats in Putalibazar Municipality from November 2021 to May 2022.

Habitat	Shannon − Wiener diversity index (H')	Evenness (J)
Agricultural Land	2.293	0.809
Settlement	2.184	0.806
Forest	2.167	0.765
River basin	2.104	0.742
Total (Overall)	2.372	0.805

4.2 Power-line Affected Avian Species

Forty three individuals of 11 different species were found the victims of power line related mortality (Figure 3; Appendix 2). A total of 26 electrocuted birds of eight species were found dead, and these were noticed in 15% plots (n = 18). The average nest count in the observation plot was 0.06 ± 0.329 (mean ± SD) (range: 0 to 2). The most electrocuted species was House Crow (*Corvus splendens*; n = 11) followed by Rock Pigeon (*Columba livia*; n = 5; Appendix 4). Total electrocution rate was 2.22 per 10 poles (Appendix 4). No relationship was found between species-specific electrocution rates and their abundances (Coefficient ± S.D = 0.6119 ± 0.10386, p = 0.5702).

In case of collisions, 17 individuals of six different species were recorded out of which Common Myna (*Acridotheres tristis*; n = 6), and House Swift (*Apus nipalensis*; n = 5) shared the highest collision rates (Appendix 4). Total avian power line collision rate was 0.55 birds per km (Appendix 4).

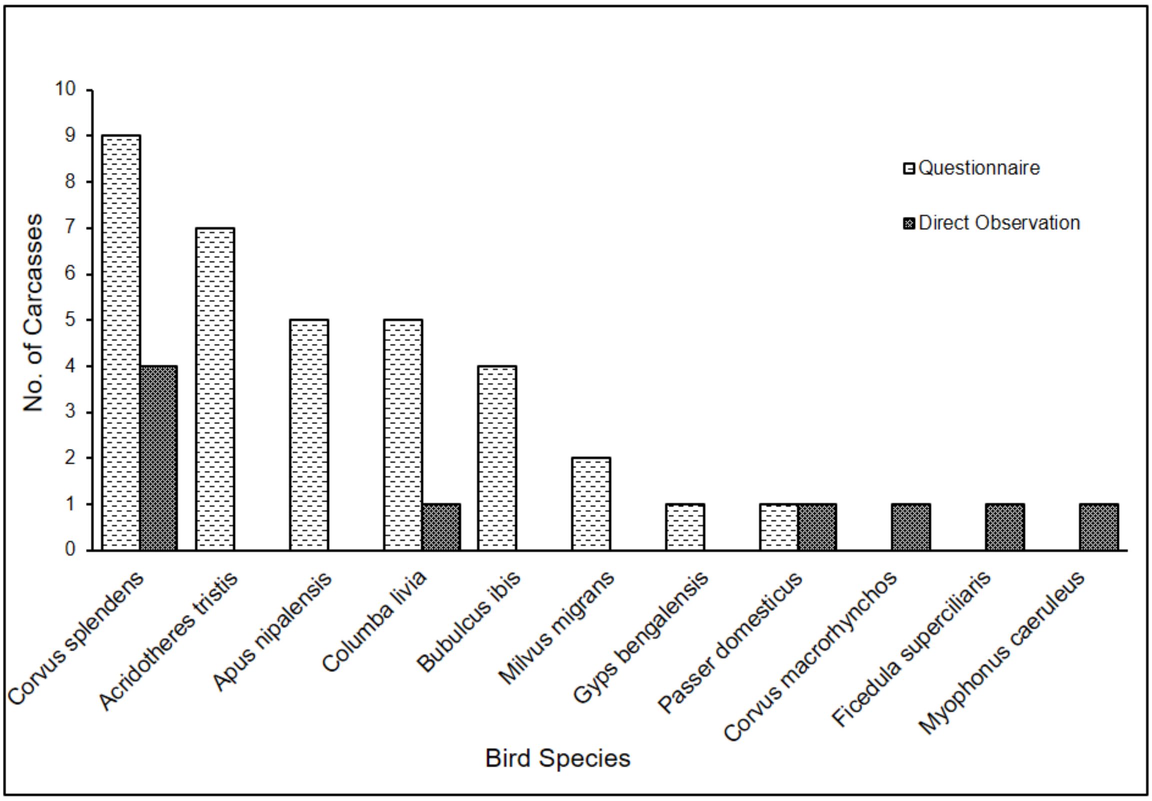

Figure 3: Carcasses record of Avian Species in Putalibazar Municipality from November 2021 to May 2022

4.3 Factors Affecting Avian Electrocution and Power-line Collision

The average trees count in the observation plots was 1.085 ± 2.090 (SD) [range: 0 − 16] and the average birds count was 7.325 ± 5.240 (SD) [range: 0 − 32]. The average forest canopy was 19.920 ± 30.181 % (SD) [range: 0 − 95.68%]. The average nearest distance from the observation plot to agricultural land was 35.09 ± 48.38 m (SD) [range: 0 − 258 m], forest was 46.18 ± 54.72 m (SD) [range: 0 − 292 m], settlement was 51.66 ± 60.75 m (SD) [range: 0 − 292 m], and water source was 175.4 ± 172.21 m (SD) [range: 4 − 712 m]. The average carcass count for the observation plot was 0.367 ± 0.772 (SD) [range: 0 − 4].

Table 2: Logistic regression models describing the power line related avian mortality in Putalibazar Municipality (Figure 1) from November 2021 to May 2022, ranked according to the Akaike Information Criterion adjusted for small sample size (AICc). Model parameters include Voltage (kV), Birds Abundance, Forest Canopy Cover (%), Distance to Agricultural Land (m), Distance to Forest (m), Distance to Settlement (m), and Distance to Water Source (m) as predictive variables and Bird's Mortality as response variable. K is the number of parameters, ΔAICc is the difference between the AICc value of the best supported model and successive models and Wi is the Akaike Model Weight**.**

Covariates	K	ΔAICc	Wi
Birds Abundance + Distance to Agricultural Land + Distance to Settlement	4	0	0.268
Birds Abundance + Distance to Agricultural Land + Distance to Settlement + Voltage	5	2.027	0.097
Birds Abundance + Forest Canopy Cover + Distance to Agricultural Lands + Distance to Settlement	5	2.088	0.094
Birds Abundance + Distance to Agricultural Land + Distance to Forest + Distance to Settlement	5	2.092	0.094
Birds Abundance + Distance to Agricultural Lands + Distance to Settlement + Distance to Water Source	5	2.165	0.091

The best supported model was found with the variables including bird abundance, distance to nearest agricultural land, and settlement followed by the model containing bird abundance, distance to nearest agricultural land, distance to nearest settlement, and voltage (Table 2; Appendix 5).

Table 3: Model averaged parameter estimates at 95 % Confidence Limits (CL) describing the effects of given predictors on power line related avian mortality in Putalibazar Municipality (Figure 1) from November 2021 to May 2022. Model parameters include voltage (kV), forest canopy cover (%), birds count, distance to water (m), distance to agricultural land (m), distance to forest (m), and distance to settlement (m). Estimates were averaged from all models. (SE = Standard Error, LCI= Lower Confidence Interval, UCI= Upper Confidence Interval) *Significant effects are in bold.

Parameters	**Estimate**	**S.E**	**LCI**	**UCI**	**Z**	**P**
Intercept	-0.104	0.861	-1.812	1.619	-0.121	0.903
Voltage	-0.366	0.662	-1.672	0.966	-0.554	0.579
Forest canopy	0.003	0.011	-0.020	0.025	0.297	0.766
Birds abundance	0.128	0.053	0.029	0.240	2.412	**0.015**
Distance to water	-0.0004	0.001	-0.004	0.002	-0.259	0.796
Distance to Agricultural Land	-0.029	0.013	-0.059	-0.008	-2.278	**0.022**
Distance to Forest	-0.001	0.005	-0.012	0.008	-0.298	0.765
Distance to Settlement	-0.030	0.010	-0.054	-0.012	-2.823	**0.004**

The probability of power line related avian mortality was less in plots with greater voltage along with increasing distance to water, agricultural land, forest, and settlement (Table 3). Greater forest canopy showed increased probability for avian mortality but the effect was not significant. Bird abundance, distance to agricultural land, and distance to settlement showed significant role in avian mortality (Table 3). Power lines related avian mortality increased with bird's abundance in and along the study sites whereas it decreased significantly with the increase in distance to the agricultural land and the settlement (Table 3).

5. DISCUSSION

In this study, avian survival is affected by power line collisions and electrocution in Putalibazar Municipality. The occurrence of higher number of order Passeriformes in this study might be due to the migratory birds or the residential behavior of the birds. The order Passeriformes commonly includes perching birds, and is also regarded as the dominant avian group (Grimmett et al. 2016). The highest bird diversity in agricultural lands might be due to the greater availability of food in the agricultural lands. Field margins and forest patches enhance the landscape complexity of agricultural landscapes and thus provide essential refugia for diverse insect communities (Dennis and Fry 1992, Mineau and McLaughlin 1996). House Crow and Rock Pigeon were found to be the most electrocuted bird species, which might be due to their greater availability and larger wingspan to complete the circuit between any two energized parts (Janss 2000). Common Mynah and House Swift were found to be the most affected by power line collisions, which might be due to their shorter wingspan and swift maneuverability (Janss 2000).

Lower voltage, i.e., 11 kV was found to have a greater probability of power line related avian mortality. Lower voltage power lines have comparatively shorter clearances between energized parts, which lead to greater susceptibility of the birds to electrocution and collision risks (Bevanger 1998, Janss 2000, Kemper et al. 2013). Low (15 kV) and middle voltage (33 kV) lines have been found to be dangerous for large birds such as raptors, storks, and owls, which are more likely to short-circuit while resting if they come into contact with more than one conducting wire (Battaglini and Bätjer 2015).

The forest canopy cover had a positive effect, but the effect was not notably significant. Moderate forest canopy cover supports higher bird populations by providing shelter, which might increase the risks for power line related avian fatalities (Hernández-Lambraño et al. 2018).

Bird abundance had significant effects on the power lines related avian mortality. The greater the abundance, the greater the probability, which might be due to the high crowd and sensitivity of birds to electrocution risks (Lehman et al. 2007) .

Avian mortality due to power lines was found to be weakly related to distance to water from the study sites. The lesser the distance to the water source, the greater the probability of the avian power line fatalities, which was probably due to the heavy usage of those habitats by birds and their frequent movement towards water sources crossing the power lines (Faanes 1987).

The closer the distance to the agricultural land, the greater the possibility for the power lines related avian fatalities. Bird electrocution is common in high proportion in the agricultural land since the birds use the power lines and poles as perching points in search of their prey (Perez-Garcia et al. 2011). In addition to that, agricultural land hosts many bird species that are likely to suffer power line related fatalities due to the ever increasing number of power lines built on agricultural land, where the terrain conditions are more suitable for the installation of utility structures (Siriwardena et al. 1998, Donald et al. 2001, Wretenberg et al. 2006). Also, the quick encounter and detection of avian fatalities due to power lines closer to the agricultural land is probably high due to the frequent visits of the local farmers in and around the field.

The effect of forest was not found significant. However, its effect was seen negative. The greater the distance to forest, the lesser was the probability of avian electrocution or collisions. Power lines in close vicinity to bird congregation habitats like forests are found to be the most hazardous, since the birds establish breeding and wintering colonies and concentrate at higher densities dramatically affecting the likelihood of collision (Malcolm 1982, Faanes 1987, Andriushchenko and Popenko 2012). Avian species from forested habitats are prone to collisions, particularly due to higher power lines than adjacent tree tops (Bevander 1990, Bevanger and Brøseth 2004, Mojica et al. 2009).

The distance to settlement had a significant negative association with the power lines related avian mortality. The avian mortality due to power lines was seen higher at places closer to human settlement since the birds tend to avoid the noises and transportation disturbances at settlement areas which might lead them to encounter with the power lines causing them electrocution or collision victims (Krapu 1974). Furthermore, probability of identification and detection of the avian outages and casualties is also higher within settlement areas which provide a basis for its significant effect on avian mortality.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Avian mortality due to electrocution and power line collisions in Putalibazar Municipality was seen to be frequent, which may have adverse effects on the bird species and their abundance. The most affected electrocution victims included House Crow and Rock Pigeon, whereas the most affected power line collision victims included Common Myna and House Swift. Various environmental factors such as bird abundance, distance to agricultural land, and anthropogenic factors such as distance to settlement were found to have significant associations with the probability of avian mortality due to power lines.

6.2 Recommendations

The study was based on the data of six months. The study on the effects of various other probable contributing factors for avian electrocution and collision risks such as bird morphology, behavior, and electric fittings were lacking due to time and technical constraints. Therefore, further study on the bird’s morphology, behavior, and electric fittings is recommended for further research. Seasonal data comparison may provide additional information about the effects of season. Fitting colored bird diverters onto the power lines will help control the probable risks of avian electrocution and power line collisions. The careful route planning of the power distribution lines and the timely supervision of the power distribution lines should be undertaken alongside to minimize the probable risks for avian fatalities.

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APPENDICES

Appendix 1: Checklist of Avian Species at Putalibazar Municipality from November 2022 to May 2022

S.N	Common Name	Scientific Name	Order	Family	No. of individuals	IUCN	National Red List
1	Black Bulbul	*Hypsipetes leucocephalus*	Passeriformes	Pycnonotidae	26	LC	LC
2	Black Drongo	*Dicrurus macrocercus*	Passeriformes	Dicruridae	15	LC	LC
3	Black Kite	*Milvus migrans*	Accipitriformes	Accipitridae	44	LC	LC
4	Blue Whistling-thrush	*Myophonus caeruleus*	Passeriformes	Muscicapidae	18	LC	LC
5	Cattle Egret	*Bubulcus ibis*	Pelecaniformes	Ardeidae	42	LC	LC
6	Common King Fisher	*Alcedo atthis*	Coraciformes	Alcedinidae	19	LC	LC
7	Common Myna	*Acridotheres tristis*	Passeriformes	Sturnidae	273	LC	LC
8	House Crow	*Corvus splendens*	Passeriformes	Corvidae	132	LC	LC
9	House Sparrow	*Passer domesticus*	Passeriformes	Passeridae	69	LC	LC
10	House Swift	*Apus nipalensis*	Caprimulgiformes	Apodidae	48	LC	LC

11	Large-billed Crow	*Corvus macrorhynchos*	Passseriformes	Corvidae	41	LC	LC
12	Little Egret	*Egretta garzetta*	Pelecaniformes	Ardeidae	26	LC	LC
13	Red Junglefowl	*Gallus gallus*	Galliformes	Phasianidae	7	LC	LC
14	Rock Pigeon	*Columba livia*	Columbiformes	Columbidae	32	LC	LC
15	Rose-ringed Parakeet	*Alexandrinus krameri*	Psittaciformes	Psittaculidae	16	LC	LC
16	Ultramarine Flycatcher	*Ficedula superciliaris*	Passeriformes	Muscicapidae	14	LC	LC
17	Western Koel	*Eudynamys scolopaceus*	Cuculiformes	Cuculidae	11	LC	LC
18	Western Spotted Dove	*Spilopelia suratensis*	Columbiformes	Columbidae	16	LC	LC
19	White-rumped Vulture	*Gyps bengalensis*	Accipitriformes	Accipitridae	4	CR	CR
Total					**853**	**-**	**-**

IUCN=International Union for Nature Conservation, LC=Least Concern, CR=Critically Endangered

Appendix 2: Total orders and families of the avian species recorded in Putalibazar Municipality from November 2021 to May 2022

S.N	Order	Families	No. of Species
1	Accipitriformes	Accipitridae	2
2	Caprimulgiformes	Apodidae	1
3	Columbiformes	Columbidae	2
4	Coraciformes	Alcedinidae	1
5	Cuculiformes	Cuculidae	1
6	Galliformes	Phasianidae	1
7	Passeriformes	Corvidae	2
		Dicruridae	1
		Muscicapidae	2
		Passeridae	1
		Pycnonotidae	1
		Sturnidae	1
8	Pelecaniformes	Ardeidae	2
9	Psittaciformes	Psittaculidae	1

Appendix 3: Carcasses record of the survey and the conservation status of the avian species according to IUCN (2011): LC (Least Concern), CR (Critically Endangered).

S.N	Common Name	Scientific Name	Order	IUCN List	Direct Observation	Questionnaire	Total
1	Black Kite	*Milvus migrans*	Accipitridiformes	LC	0	2	2
2	Blue Whistling-thrush	*Myophonus caeruleus*	Passeriformes	LC	1	0	1
3	Cattle Egret	*Bubulcus ibis*	Pelecaniformes	LC	0	4	4
4	Common Myna	*Acridotheres tristis*	Passeriformes	LC	0	7	7
5	House Crow	*Corvus splendens*	Passeriformes	LC	4	9	13
6	House Sparrow	*Passer domesticus*	Passeriformes	LC	1	1	2
7	House Swift	*Apus nipalensis*	Caprimulgiformes	LC	0	5	5
8	Large-billed Crow	*Corvus macrorhynchos*	Passeriformes	LC	1	0	1
9	Rock Pigeon	*Columba livia*	Columbiformes	LC	1	5	6
10	Ultramarine Flycatcher	*Ficedula superciliaris*	Passeriformes	LC	1	0	1
11	White-rumped Vulture	*Gyps bengalensis*	Accipitridiformes	CR	0	1	1
Total					**9**	**34**	**43**

Appendix 4: Avian mortality by electrocution and collision in distribution lines (11 kV and 33 kV) in Putalibazar Municipality from November 2021 to May 2022.

S.N	Species	Electrocution	Collision	Relative Abundance	Electrocution/10 poles	Collision/Km	IUCN
1	*Acridotheres tristis*	1	6	0.32	0.09	0.19	LC
2	*Apus nipalensis*	0	5	0.06	0	0.16	LC
3	*Bubulcus ibis*	4	0	0.05	0.34	0	LC
4	*Columba livia*	5	1	0.04	0.43	0.03	LC
5	*Corvus macrorhynchos*	1	0	0.05	0.09	0	LC
6	*Corvus splendens*	11	2	0.15	0.94	0.07	LC
7	*Ficedula superciliaris*	0	1	0.02	0	0.03	LC
8	*Gyps bengalensis*	1	0	0.02	0.08	0	CR
9	*Milvus migrans*	2	0	0.05	0.17	0	LC
10	*Myophonus caeruleus*	1	0	0.004	0.08	0	LC
11	*Passer domesticus*	0	2	0.08	0	0.07	LC
	Total				**2.22**	**0.55**	

Appendix 5: Logistic regression models describing the power line related avian mortality in Putalibazar Municipality Nepal (Figure 1) from November 2021 to May 2022, ranked according to the Akaike Information Criterion adjusted for small sample size (AICc). Model parameters include Voltage (kV), Birds Abundance, Forest Canopy Cover (%), Distance to Agricultural Land (m), Distance to Forest (m), Distance to Settlement (m), and Distance to Water (m) as predictive variables and Bird's Mortality as response variable. K is the number of parameters, ΔAICc is the difference between the AICc value of the best supported model and successive models and Wi is the Akaike Model Weight.

Models	K	AICc	ΔAICc	Wi
Birds Abundance + Distance to Agricultural Land + Distance to Settlement	4	103.594	0	0.268
Birds Abundance + Distance to Agricultural Land + Distance to Settlement + Voltage	5	105.622	2.027	0.097
Birds Abundance + Forest Canopy cover + Distance to Agricultural Land + Distance to Settlement	5	105.682	2.088	0.094
Birds Abundance + Distance to Agricultural Land + Distance to Forest + Distance to Settlement	5	105.687	2.092	0.094
Birds Abundance + Distance to Agricultural Land + Distance to Settlement + Distance to Water	5	105.759	2.165	0.091
Birds Abundance + Distance to Agricultural Land + Distance to Forest + Distance to Settlement + Voltage	6	107.688	4.093	0.034
Birds Abundance + Forest Canopy Cover + Distance to Agricultural Land + Distance to Settlement + Voltage	6	107.703	4.108	0.034

Birds Abundance + Distance to Agricultural Land + Distance to Settlement + Distance to Water + Voltage	6	107.778	4.183	0.033
Birds Abundance + Forest Canopy Cover + Distance to Agricultural Land + Distance to Forest + Distance to Settlement	6	107.856	4.261	0.031
Birds Abundance + Forest Canopy Cover + Distance to Agricultural Land + Distance to Settlement	6	107.889	4.294	0.031
Birds Abundance + Distance to Agricultural Land + Distance to Forest +Distance to Settlement + Distance to Water	6	107.898	4.303	0.031
Distance to Agricultural Land + Distance to settlement	3	108.342	4.747	0.025
Birds Abundance + Forest Canopy Cover + Distance to Agricultural Land + Distance to Forest +Distance to Settlement + Voltage	7	109.870	6.276	0.011
Birds Abundance + Distance to Agricultural Land + Distance to Forest +Distance to Settlement + Distance to Water + Voltage	7	109.891	6.296	0.011
Null	**1**	**128.442**	**24.847**	**1.08E-06**

PHOTO PLATES

Common Myna
(*Acridotheres tristis*)

Black Drongo
(*Dicrurus macrocercus*)

Large-billed Crow
(*Corvus macrorhynchos*)

House Sparrow
(*Passer domesticus*)

Little Egret
(*Egretta garzetta*)

Cattle Egret
(*Bubulcus ibis*)

Black Kite
(*Milvus migrans*)

Blue Whistling-thrush
(*Myophonus caeruleus*)

Western Spotted Dove
(*Spilopelia suratensis*)

Western Koel
(*Eudynamys scolopaceus*)

Common Kingfisher
(*Alcedo atthis*)

Rock Pigeon
(*Columba livia*)

Bird species found in the Putalibazar Municipality, Syangja, Nepal


House Sparrow
(*Passer domesticus*)


Ultramarine Flycatcher
(*Ficedula superciliaris*)


Large-billed Crow
(*Corvus macrorhynchos*)


Rock Pigeon
(*Columba livia*)


Blue Whistling-thrush
(*Myophonus caeruleus*)

Carcasses of different birds caused by electrocution or power line collision found in the Putalibazar Municipality, Syangja, Nepal