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Original Article

Riverine forest as a significant habitat to harbor a wide range of bird species

Floresta ribeirinha como hábitat significativo para abrigo de uma gama de espécies de aves

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Abstract

Riverine forests are unique and highly significant ecosystems that are globally important for diverse and threatened avian species. Apart from being a cradle of life, it also serves as a gene pool that harbors a variety of flora and fauna species (repeated below). Despite the fact, this fragile ecosystem harbored avian assemblages; it is now disappearing daily as a result of human activity. Determining habitat productivity using bird species is critical for conservation and better management in the future. Multiple surveys were conducted over a 15-month period, from January to March 2019, using the distance sampling point count method. A total of 250 point count stations were fixed systematically at 300 m intervals. In total, 9929 bird individuals were recorded, representing 57 species and 34 families. Out of 57 bird species, two were vulnerable, one was data deficient, one was nearly threatened, and the remaining 53 species were of least concern. The Eurasian Collard Dove – *Streptopelia decaocto* (14.641 ± 2.532/ha), White-eared Bulbul – *Pycnonotus leucotis* (13.398 ± 4.342/ha) and Common Babbler – *Turdoides caudata* (10.244 ± 2.345/ha) were the three first plenteous species having higher densities. However, the densities of three species, i.e., Lesser Whitethroat – *Sylvia curruca*, Gray Heron – *Ardea cinerea* and Pallas Fish Eagle – *Haliaeetus leucoryphus,* were not analyzed due to the small sample size. The findings of diversity indices revealed that riverine forest has harbored the diverse avian species that are uniformly dispersed across the forest. Moreover, recording the ten foraging guilds indicated that riverine forest is rich in food resources. In addition, the floristic structure importance value index results indicated that riverine forest is diverse and rich in flora, i.e. trees, shrubs, weeds and grass, making it an attractive and productive habitat for bird species.

Keywords: Keystone, birds, riverine forest, Kot Dinghano, habitat, diversity.

Resumo

As florestas ribeirinhas são ecossistemas únicos e altamente significativos que são globalmente importantes para diversas espécies de aves ameaçadas de extinção. Além de serem o berço da vida, também servem como um conjunto genético que abriga uma variedade de espécies da flora e da fauna. Apesar disso, esse frágil ecossistema abrigava um conjunto de aves, mas agora está desaparecendo diariamente como resultado da atividade humana. Determinar a produtividade do hábitat usando espécies de pássaros é fundamental para a conservação e melhor gestão no futuro. Vários levantamentos foram realizados ao longo de um período de 15 meses, de janeiro de 2018 a março de 2019, por meio do método de contagem de pontos de amostragem de distância. Foram fixadas sistematicamente 250 estações de contagem de pontos em intervalos de 300 m. No total, foram registrados 9.929 indivíduos de aves, representando 57 espécies e 34 famílias. Das 57 espécies de aves, duas eram vulneráveis, uma tinha dados insuficientes, uma estava quase ameaçada e as 53 espécies restantes eram as menos preocupantes. O: Pomba de colar euroasiática - *Streptopelia decaocto* (14.641 ± 2.532/ha), o Bulbul de orelha branca - *Pycnonotus leucotis* (13.398 ± 4.342/ha) e Tagarela comum - *Turdoides caudata* (10.244 ± 2.345/ha) foram as três primeiras espécies abundantes com maiores densidades. No entanto, as densidades de três espécies, Papa-amoras-cinzento (*Sylvia curruca*), Garça-real-europeia (*Ardea cinerea*) e Águia-pescadora de Pallas (*Haliaeetus leucoryphus*), não foram analisadas por causa do pequeno tamanho da amostra. Os resultados dos índices de diversidade revelaram que a floresta ribeirinha abrigou diversas espécies de aves que estão uniformemente dispersas pela floresta. Além disso, o registro das dez guildas de forrageamento indicou que a floresta ribeirinha é rica em recursos alimentares. Além disso, os resultados do índice de valor de importância da estrutura florística indicaram que a floresta ribeirinha é variada e rica em flora, ou seja, árvores, arbustos, ervas daninhas e grama, tornando-a um hábitat atraente e produtivo para espécies de aves.

Palavras-chave: Keystone, pássaros, floresta ribeirinha, Kot Dinghano, hábitat, diversidade.

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1. Introduction

Conservation status and population structure reflect habitat productivity and the effects of human footprints on bird populations and habitat (Thompson III et al., 2002; DeSante et al., 2005; Kaminski et al., 2006; Gregory et al., 2006). This might be because bird species play a noteworthy role in seed dispersal and pest control (Dale et al., 2002; Ellison et al., 2005; Morrison, 2009; Caro, 2010). The population attributes of birds reflects long-term temporal changes in floral cover, forest management operations, and threats posed by anthropogenic activities, as certain species become threatened, endangered, or vulnerable as a result of these activities (Burger, 2006).

Riverine forest is an area where the land and river interface. These forest areas are hotspots of aquatic and terrestrial biodiversity, with a wide range of floral structures (trees, shrubs, and grasses) and fauna (mammals, birds, amphibians, and reptiles) (Ward et al., 2002; Amitha Bachan, 2003; Capon et al., 2016). They are dominated by hydrophilic plants, which can thrive in both wet and dry environments. These forests provide a safe haven for a diverse range of bird species.

Furthermore, riverine forests is prolific ecosystem, it serves as a gene pool flora, raw material for medications, critical habitat for wide range of bird species and ample food resources. Due to the strong reliance of local residents on agriculture, riverine forests are at the forefront of conservation and protection. They are also hotspots for agricultural production. Despite the fact that these forests are crucial, they are under severe threat from overexploitation, uncontrolled grazing, fuel wood collection, agricultural development, and border conflicts (Stave et al., 2007; Merawi, 2016).

The productivity of riverine forests using bird assemblages has received little attention, and its significance is frequently underestimated. Human interventions in Pakistan have resulted in the loss and degradation of vast riverine forest areas, resulting in a fall in bird populations. The number of many bird species has plummeted at an alarming rate as a result of habitat loss and degradation caused by human footprints in land use patterns, unregulated use of pesticides, illegal hunting and trapping. For example, due to human involvement, Sociable Lapwing – *Vanellus gregarious,* Jerdon's Babbler – *Moupinia altirostris,* Marbled Duck – *Marmaronetta angustriostris,* Sarus Crane – *Grus antigone,* Ferruginous Duck – *Aythya nyroca,* Lesser White–fronted Goose – *Anser erythropus* and White-headed Duck – *Oxyura leucocephala* (Sekercioğlu et al., 2004; Khalique et al., 2012; Khan and Ali, 2015; Umar et al., 2018) have become vulnerable and endangered.

Unfortunately, no research has been done utilizing bird assemblages to analyze the productivity of riverine forests across the country. As a result, this study was carried out to determine productivity through bird assemblages to improve future management plans and conservation (Hill et al., 2001; Cahill et al., 2006).

2. Materials and Methods

2.1. Study area

This research took place in the Kot Dinghano Riverine Forest, which is located along the right bank of the Indus River Lakhat between 101°10' and 101°50' longitude and 2°50' and 3°00' latitude (Figure 1) in the district of Shaheed Banazirabad in Sindh, Pakistan. This riverine forest is approximately 4000 acres in size and has unique characteristics, such as a heterogeneous landscape made up of forests, marshes, and agricultural areas, which represent

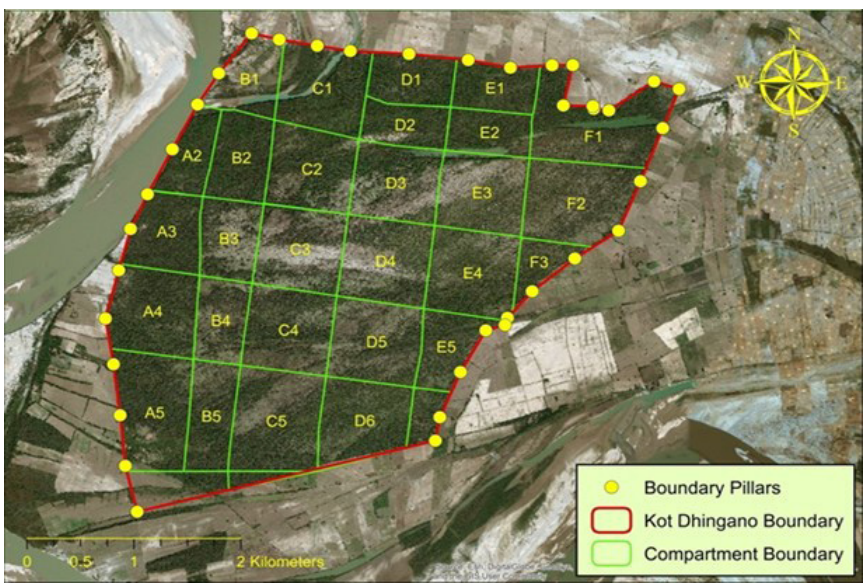

Figure 1. Location map of the study area. A-F = The names of compartments.

special environmental conditions for attracting game and nongame birds. The riverine forest is rich in floral structure (Figure 2), food supplies, and nesting grounds, all of which have the potential to attract bird species.

2.2. Survey of bird species

Bird surveys were performed employing the distance sampling point count method for 15 consecutive months from January 2018 to March 2019. The distance sampling point count method is one of the most quantitative and robust techniques to examine population structure and habitat characteristics (Verner and Purcell, 1999; Codesido and Bilenca, 2000) across different habitats. This method involves the visual and auditory detection of birds with fixed or variable radius plots and provides important information on the bird population structure and habitat characteristics (Verner and Ritter, 1985; Mills et al., 2000). Bird detection in the riverine forest environment, on the other hand, may vary based on floral foliage density, canopy cover, visibility, sound perception, and observer competence (Schieck, 1997; Whitman et al., 1997; Blake and Loiselle, 2000).

To avoid double counting the same bird individuals at more than one station, a total of 250 point count stations were randomly placed at 300 m intervals. The birds were surveyed at each point count station for 15 minutes (Freeman et al., 2003; Lee and Marsden, 2008). The distance from the bird to the observer was recorded using visual estimation within 100 m long distance bands. The surveys were conducted between 7:00 a.m. and 11:00 a.m. This is the best time to go because the majority of the birds were active in performing multiple activities. Flying birds, on the other hand, were not documented since their originating locations were unknown. The sampling methodology was followed as prescribed by Buckland (2006), Sutherland (2006), Nadeau et al. (2008) and Thomas et al. (2010).

2.3. Floral survey

One of the most significant factors is determining the structure and content of floral species composition and cover. This might be because it shows how much area is covered by vegetation (such as trees, shrubs, weeds, and grasses), as well as the habitat structure, appropriateness, and productivity for bird species to thrive. The quadrat technique was used to determine the floral structure. In this study, quadrates of various sizes were used, e.g., 20x20 m for trees, 5x5 m for shrubs and 1x1 m for grasses and weeds, to examine the floral species composition and cover percentage. The methodology was followed as stated by Keighery (1994), Barker (2001), Clarke (2009) and Schulz et al. (2009).

3. Data Analysis

3.1. IUCN conservation status

The IUCN Red List was used to determine the conservation status of detected bird species (IUCN, 2018).

3.2. Relative abundance

Relative abundance is the number of bird individuals of a particular species that occupied the riverine forest habitat (Bibby et al., 2000). The relative abundance of birds varies with altitude, aspect, microclimate conditions, geographic distribution, and restoration efforts (McGill et al., 2007; Verberk, 2011). The relative abundance of riverine forest bird species was determined using Equation 1:

Figure 2. Aesthetic view of the riverine forest habitat.

$$\text{Relative Species Abundance } (\%) = I\,\text{si}/\sum N\ \text{si X } 100 \quad (1)$$

where, ISi = total number of bird individuals of overall detected bird species, /∑Nsi = observed total number of bird species (Anderson et al., 2015).

3.3. Bird density

The number of birds per hectare is known as bird density. Determining the current population of bird species that occupy riverine forests is critical for future management and conservation efforts. The bird population was determined through DISTANCE Software (Version 7.1) by Buckland et al. (2004).

The "detection function" g (y), i.e., the probability of the birds at distance y, is determined by sampling the distribution of recorded distances between observer and object. This aids in determining the mean probability of spotting a bird within w of the point, marked Pa, at a particular position. The bird density can be determined using Equation 2:

$$\hat{D} = \frac{1}{a}\sum_{i=1}^{n}\frac{1}{\hat{P}_a(\mathbf{z}_i)} \quad (2)$$

where, *a is* the size of the covered region, *n is* the number of birds seen, and *P^ a* (**z***i*) is the estimated probability of detecting the *i*th bird given that it is within *w* of the point and has the covariate values **z***i* (Marsden, 1999; Buckland, 2006).

3.4. Diversity indices

The diversity indices, i.e., Species diversity (variability), species richness and species evenness (distribution) reflect the productivity and biodiversity of a particular area. Ascertaining the diversity indices in riverine forests indicates that either biodiversity resources are expanding or diminishing or it will be useful in developing wildlife management and conservation plans in the future, particularly for bird species. Community Analysis Package Software (CAP: version 4.0) by Henderson and Seaby (2007) was used to determine diversity indices such as Shannon's Diversity Index, Margalef's Richness Index, and Pielou J Evenness Index to estimate the appropriateness of riverine habitat for a wide range of bird species.

3.4.1. Shannon's diversity index

It is an index that takes into account the number of different bird species that occur in riverine forests, as well as their relative abundance. It provides data on the rarity and abundance of birds in riverine forests. Shannon's diversity index formula was used to calculate the bird species diversity of riverine forests, as shown below (equation 3):

$$H' = \sum[(pi)\times In(pi)] \quad (3)$$

where, H' designates diversity, S indicates the number of bird species, *i* specifies the abundance of bird species, *N* is the total number of all bird individuals, p_i is the bird relative abundance of each species, and ln is the natural logarithm.

3.4.2. Simpson's diversity index

It is an index that takes into account the number of bird species found in riverine forests, as well as their relative abundance. It gives more weight to dominating bird species than unusual bird species. It is frequently used to measure habitat productivity. Simpson's diversity index formula was used to estimate the bird species diversity of riverine forests (Equation 4):

$$D = 1 - \Sigma n(n-1)/N(N-1) \quad (4)$$

Where, *pi* = the proportion (n/N) of individuals of one particular bird species (n), N = the total number of bird individuals, Σ = the sum of the calculations of bird species (Glen, 2021).

3.4.3. Margalef's richness index

Species richness is a measure of the number of bird species detected in riverine forests. Margalef's richness index formula was used to assess the bird species richness of riverine forests (Equation 5):

$$R = (S-1)/\ln N \quad (5)$$

where, S is the total number of species and N is the total number of individuals in the sample.

3.4.4. Pielou J evenness index

The distribution of bird abundance over the riverine forest is described as species evenness. It depicts the distribution of bird species in riverine forests. The Pielou J evenness index formula was used to determine the evenness of bird species in riverine forests (Equation 6):

$$J = H/\log(S) \quad (6)$$

where, H = is the observed Shannon-Wiener index and S = is the total number of bird species in the coniferous forest.

3.5. Foraging guild structure

A foraging guild structure is a group of bird species that use comparable food resources and capture them in the same or different ways. The bird species were grouped into ten groups. The methodology was followed as described by Graaf et al. (1985), Ehrlich et al. (1988), and Thorngate et al. (2006).

3.6. Vegetation importance value index

The significance of trees, shrubs, weeds, and grasses in riverine forest habitats is indicated by the importance value index. It takes into account the relative value of each

species' density, frequency, and relative cover, all of which show the ecological relevance of the riverine forest's floral structure. The importance value index identifies the most dominant and rarest flora in riverine habitats, as well as their potential productivity. The following formula was used to calculate the value of vegetation structure (IVI) of riverine forest habitat (Equation 7):

$$IVI = RF + RD + RC \quad (7)$$

where, RF = relative frequency, RD = relative density and RC =/r/relative cover.

3.7. Relative density (RD)

The number of individuals of a given plant species per unit area is known as density (ha or ^{km2}). Relative density (RD) is the proportion of each plant species' contribution to the total number of plants in an area. The relative density of riverine forest flora was calculated using the formula below (Equation 8):

$$RD = \frac{No.\ of\ individuals\ of\ each\ plant\ species\ total\ number\ of\ plant\ individuals\ of\ all\ detected\ plant\ species}{} \quad (8)$$

3.8. Relative frequency (RF)

A plant species' frequency can be defined as a proportion of the quadrate in which it occurs. The relative frequency (RF) is a frequency that is expressed as a percentage of the overall frequency. The following formula was used to compute the relative frequency of riverine forest flora species (Equation 9):

$$RF = \frac{No\ of\ quadrate\ in\ which\ plant\ species\ occur\ Total\ No.\ of\ quadrate\ taken}{} \quad (9)$$

4. Results

4.1. Bird species composition and relative abundance

In total, 9929 bird individuals were recorded using the distance sampling point count approach, belonging to 57 species and 34 families. Based on the IUCN Red List, two species were vulnerable (VU), one was data deficient (DD), one was nearly threatened (NT), and the remaining 53 species were of least concern (LC). The Eurasian Collard Dove – *Streptopelia decaocto* (15.56%), White-eared Bulbul – *Pycnonotus leucotis* (11.94%), and Gray Francolin – *Francolinus pondicerianus* (10.17%) were the three foremost dominant bird species having the highest relative abundance in the Kot Dinghano Riverine forest. In contrast, Lesser Whitethroat – *Sylvia curruca* (0.07%), Gray Heron – *Ardea cinerea* (0.06%), and Pallas Fish Eagle – *Haliaeetus leucoryphus* (0.05%) were the rarest riverine forest bird species (Table 1).

4.2. Distribution of bird abundance in riverine forest habitat

4.2.1. Log series model

It is the most widely used mathematically intermediate model between the broken stick and log series. The lognormal model test revealed that bird species in the riverine forest are widely dispersed. However, sampling error may have an impact on bird species distribution in the study area (Figure 3).

4.2.2. Truncated lognormal model

This model is comprised of two parameters: (i) location and (ii) dispersion. The truncated lognormal model indicated that the distribution of bird species, both sparsely and thickly, is influenced by habitat productivity and human interference. Furthermore, the size and quantity of samples have an impact on the dispersal of the avian community (Figure 4).

4.2.3. Broken stick model

This model is widely used to find bird populations that are more or less evenly dispersed in the same habitat. The graph demonstrated that each bird species is equally plentiful or widely spread in the riverine forest (Figure 5).

4.3. Bird density

The results of distance software analysis (DSA) demonstrated that four bird species, namely,

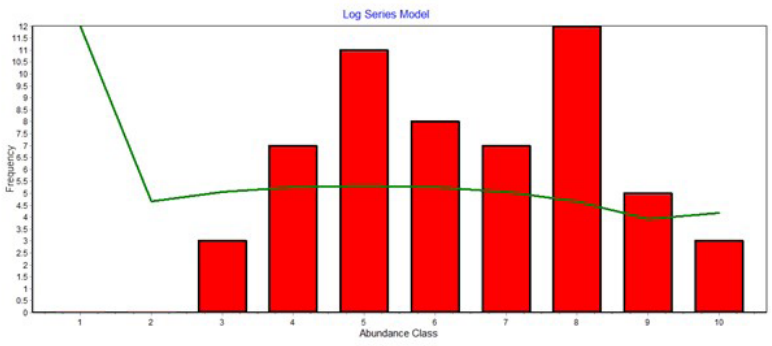

Figure 3. Log series model indicating the bird abundance of riverine forest habitat.

Table 1. Relative abundance of avian species detected in Kot Dinghano Riverine forest, Lakhat.

S. No	Scientific Name	Common Name	No of Detections	%	IUCN Status
Columbidae	*Streptopelia decaocto*	Eurasian Collard Dove	1545	15.56	LC
Pycnonotidae	*Pycnonotus leucotis*	White-eared Bulbul	1186	11.94	LC
Phasianidae	*Francolinus pondicerianus*	Gray Francolin	1010	10.17	LC
Leiothrichidae	*Turdoides striata*	Jungle Babbler	648	6.53	LC
Phylloscopidae	*Phylloscopus neglectus*	Plain Leaf Warbler	432	4.35	LC
Hirundinidae	*Riparia paludicola*	Brown-throated Sand Martin	384	3.86	LC
Scolopacidae	*Tringa totanus*	Common Redshank	340	3.42	LC
Pellorneidae	*Chaetornis striata*	Bristled Grassbird	326	3.28	VU
Leiothrichidae	*Turdoides caudata*	Common Babbler	322	3.24	LC
Ardeidae	*Ardeola grayii*	Indian Pond Heron	219	2.21	LC
Rhipiduridae	*Rhipidura aureola*	White-browed Fantail	217	2.19	LC
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	216	2.18	LC
Muscicapidae	*Phoenicurus ochruros*	Black Redstart	215	2.17	LC
Muscicapidae	*Saxicoloides fulicatus*	Indian Robin	214	2.16	LC
Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	194	1.95	LC
Ardeidae	*Egretta garzetta*	Little Egret	183	1.84	LC
Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	180	1.18	LC
Muscicapidae	*Saxicola caprata*	Pied Bush Chat	175	1.76	LC
Anatidae	*Anas strepera*	Gadwall	167	1.68	LC
Laridae	*Sterna aurantia*	River Tern	143	1.44	LC
Alcidinidae	*Ceryle rudis*	Pied Kingfisher	132	1.33	LC
Corvidae	*Corvus splendens*	House Crow	126	1.27	LC
Motacillidae	*Motacilla alba*	White Wagtail	125	1.26	LC
Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	121	1.22	LC
Muscicapidae	*Muscicapa sibirica*	Dark-sided Flycatcher	117	1.18	LC
Scolopacidae	*Tringa. Hypoleucos*	Common Sandpiper	102	1.03	LC
Ardeidae	*Egretta albus*	Great Egret	89	0.90	LC
Alcidinidae	*Halcyon smyrnensis*	White-throated Kingfisher	72	0.73	LC
Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper	58	0.59	LC
Passeridae	*Passer domesticus*	House Sparrow	55	0.55	LC
Alcidinidae	*Alcedo atthis*	Common Kingfisher	45	0.45	LC
Phylloscopidae	*Phyllosocopus inornatus*	Yellow-browed Warbler	45	0.45	LC
Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	44	0.44	LC
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	35	0.35	DD
Meropidae	*Merops orientalis*	Green Bee-eater	34	0.34	LC
Picidae	*Dinopium javanense*	Common Flameback	34	0.34	LC
Dicruridae	*Dicrurus macrocercus*	Black Drongo	32	0.32	LC
Ardeidae	*Butriodes striata*	Little Heron	29	0.29	LC
Accipitridae	*Aquila rapax*	Tawny Eagle	28	0.28	LC
Laridae	*Sterna acuticauda*	Black-bellied Tern	26	0.26	NT
Columbidae	*Spiopelia senegalensis*	Laughing Dove	26	0.26	LC
Rallidae	*Gallinula chloropus*	Common Moorhen	25	0.25	LC
Coraciidae	*Coracias benghalensis*	Indian Roller	23	0.23	LC
Podicipedidae	*Tachybaptus ruficollis*	Little Grebe	23	0.23	LC
Nectarniidae	*Cinnyris asiaticus*	Purple Sunbird	21	0.21	LC
Accipitridae	*Accipiter nisus*	Eurasian Sparrow Hawk	17	0.17	LC
Alaudidae	*Ammomanes phoenicura*	Rufous-tailed Lark	17	0.17	LC
Alaudidae	*Galerida cristata*	Crested Lark	16	0.16	LC
Accipitridae	*Accipiter virgatus*	Besra	15	0.15	LC
Cuculidae	*Centropus sinensis*	Greater Coucal	14	0.14	LC
Upupidae	*Upupa epops*	Common Hoopoe	13	0.13	LC
Scolopacidae	*Tringa glareola*	Wood Sandpiper	12	0.12	LC
Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	12	0.12	LC
Cisticolidae	*Prinia inornata*	Plain Prinia	12	0.12	LC
Sylviidae	*Sylvia curruca*	Lesser Whitethroat	7	0.07	LC
Ardeidae	*Ardea cinerea*	Gray Heron	6	0.06	LC
Accipitridae	*Haliaeetus leucoryphus*	Pallas Fish Eagle	5	0.05	VU
		Total	9929		

LC = Least Concern; VU = Vulnerable; DD = Data Deficient; NT = Nearly Threatened.

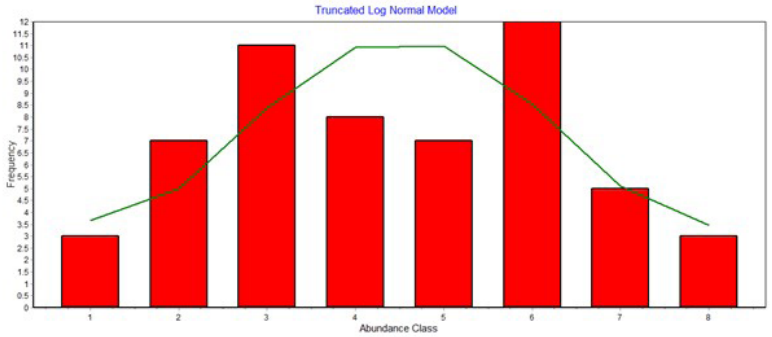

Figure 4. Truncated log normal model indicates the bird abundance of riverine forest habitat.

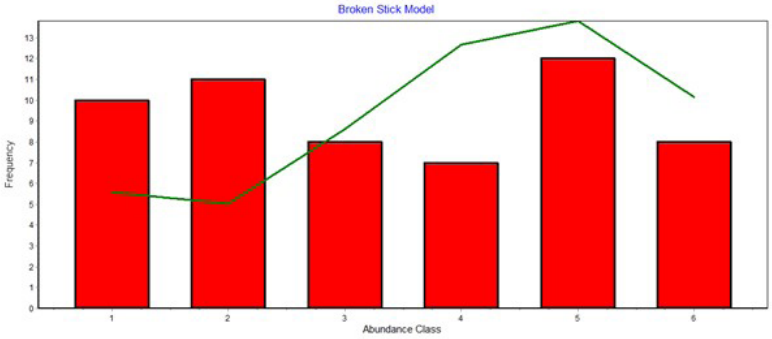

Figure 5. Broken stick model indicating the bird abundance of riverine forest habitat.

Eurasian Collard Dove – *Streptopelia decaocto* (14.641 ± 2.532/ha), White-eared Bulbul – *Pycnonotus leucotis* (13.398 ± 4.342/ha), Common Babbler – *Turdoides caudate* (10.244 ± 2.345/ha), and Gray Francolin – *Francolinus pondicerianus* (9.453 ± 4.321/ha) had highest bird density/ha. In contrast, the lowest bird density/ha was recorded for House Sparrow – *Passer domesticus* (0.231 ± 0.127/ha), followed by Small Minivet – *Pericrocotus cinnamomeus* (0.213 ± 0.121/ha) and Eurasian Sparrow Hawk – *Accipiter nisus* (0.172 ± 0.122/ha). Furthermore, the density of 3 species, i.e., Lesser Whitethroat – *Sylvia curruca,* Gray Heron – *Ardea cinerea* and Pallas Fish Eagle – *Haliaeetus leucoryphus*, was not analyzed due to the small sample size, i.e., fewer than ten individuals were detected (Table 2)

4.4. Diversity indices of bird species

In this study, diversity refers to the number of various bird species found in a Kot Dinghano Riverine forest habitat. The findings of the Community Analysis Package showed that bird species are varied (Simpson's D = 15.26 and Shannon's H' = 3.212), rich (Margalef's R_1 = 5.977) and evenness (Pielou J E = 0.798), indicating that the Kot Dinghano Riverine forest is a productive habitat. The habitat's productivity, i.e., floral characteristics and food resources attracted a diverse range of bird species to utilize riverine forest habitats (Table 3).

4.5. Foraging guilds of bird species

Notably, observed birds were divided into ten foraging guilds based on food preferences, territorial preferences, and food capture tactics. Insectivores (27.60%) were the foremost abundant guild that significantly exploited the riverine forest habitat, followed by Carnivores/Piscivores/Insectivores (18.95%) and Grainivores (15.82%). In contrast, Carnivores (0.65%), Nectarivores/Insectivores (0.21%), and Carnivores/Insectivores (0.14%) were the rarest foraging guilds in the study area. The recording of higher foraging guilds demonstrated that the food supplies in riverine forests are abundant and diversified, making it a productive habitat (Table 4).

4.6. Floristic structure and importance value index

Strikingly, the floristic structure of the Kot Dinghano Riverine forest revealed that it is diversified and abundant in floral species composition. The IVI method was used to assess the ecological significance of floral structure and species composition in the Kot Dinghano Riverine forest. The results showed that riverine forest consists of trees, shrubs, weeds, and grasses. The highest important value (23.91%) was obtained for the Gum Arabic Tree, indicating that this tree species densely occupied the riverine forest, while the lowest (2.38%) was determined for Jand, indicating that this species was rare and occupied only a small proportion of the study area. Similarly, IVI

Table 2. List of bird density (birds/ha) in Kot Dinghano Riverine forest.

Family	Scientific Name	Common Name	Density (birds/ha	Detection Probability (%)
Columbidae	*Streptopelia decaocto*	Eurasian Collard Dove	14.641 ± 2.532	98.60%
Pycnonotidae	*Pycnonotus leucotis*	White-eared Bulbul	13.398 ± 4.342	95.00%
Leiothrichidae	*Turdoides caudata*	Common Babbler	10.244 ± 2.345	89.30%
Phasianidae	*Francolinus pondicerianus*	Gray Francolin	9.453 ± 4.321	99.40%
Phylloscopidae	*Phylloscopus neglectus*	Plain Leaf Warbler	6.947 ± 2.092	99.90%
Hirundininae	*Riparia paludicola*	Brown-throated Sand Martin	6.238 ± 4.464	93.70%
Leiothrichidae	*Turdoides striata*	Jungle Babbler	4.755 ± 1.980	83.90%
Muscicapidae	*Saxicola caprata*	Pied Bush Chat	4.213 ± 0.893	99.20%
Meropidae	*Merops orientalis*	Green Bee-eater	3.763 ± 1.232	100.00%
Pycnnotidae	*Pycnonotus cafer*	Red-vented Bulbul	3.598 ± 1.672	100.00%
Rhipiduridae	*Rhipidura aureola*	White-browed Fantail	3.463 ± 0.436	98.30%
Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	2.763 ± 0.564	98.90%
Muscicapidae	*Phoenicurus ochruros*	Black Redstart	2.566 ± 0.456	99.70%
Muscicapidae	*Saxicoloides fulicatus*	Indian Robin	2.129 ± 0.980	100.00%
Anatidae	*Anas strepera*	Gadwall	2.129 ± 0.881	77.60%
Scolopacidae	*Tringa totanus*	Common Redshank	1.983 ± 0.789	98.70%
Pellorneidae	*Chaetornis striata*	Bristled Grassbird (VU)	1.899 ± 0.657	99.70%
Dicruridae	*Dicrurus macrocercus*	Black Drongo	1.873 ± 0.983	98.00%
Corvidae	*Corvus splendens*	House Crow	1.645 ± 0.781	93.20%
Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	1.214 ± 0.678	97.20%
Picidae	*Dinopium javanense*	Common Flameback	1.213 ± 0.311	99.40%
Phylloscopidae	*Phyllosocopus inornatus*	Yellow-browed Warbler	1.021 ± 0.348	98.20%
Ardeidae	*Egretta garzetta*	Little Egret	0.978 ± 0.423	98.90%
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant (DD)	0.954 ± 0.342	99.20%
Motacillidae	*Motacilla alba*	White Wagtail	0.879 ± 0.323	99.90%
Muscicapidae	*Muscicapa sibrica*	Dark-sided Flycatcher	0.870 ± 0.343	99.20%
Rallidae	*Gallinula chloropus*	Common Moorhen	0.732 ± 0.542	98.00%
Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper	0.732 ± 0.230	97.50%
Coraciidae	*Coracias bengalensis*	Indian Roller	0.682 ± 0.348/	98.50%
Ardeidae	*Butriodes striata*	Little Heron	0.678 ± 0.890	97.9%
Podicipedidae	*Tachybaptus ruficollis*	Little Grebe	0.678 ± 0.438	96.00%
Alaudidae	*Ammomanes phoenicura*	Rufous-tailed Lark	0.653 ± 0.398	97.4%
Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	0.650 ± 0.289	96.7%
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	0.649 ± 0.231	94.90%
Alcidinidae	*Halcyon smyrnensis*	White-throated Kingfisher	0.637 ± 0.213	99.40%
Upupidae	*Upupa epops*	Common Hoopoe	0.623 ± 0.489	98.90%
Ardeidae	*Ardeola grayii*	Indian Pond Heron	0.623 ± 0.320	94.60%
Laridae	*Sterna aurantia*	River Tern	0.623 ± 0.308	99.00%
Alcidinidae	*Alcedo atthis*	Common Kingfisher	0.565 ± 0.416	98.50%
Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	0.562 ± 0.342	98.00%
Scolopacidae	*Tringa glareola*	Wood Sandpiper	0.548 ± 0.348	98.90%
Alcidinidae	*Ceryle rudis*	Pied Kingfisher	0.538 ± 0.243	99.90%
Cuculidae	*Centropus sinensis*	Greater Coucal	0.532 ± 0.342	98.90%
Accipitridae	*Aquila rapax*	Tawny Eagle	0.452 ± 0.148	99.40%
Laridae	*Sterna acuticauda*	Black-bellied Tern (NT)	0.434 ± 0.252/	95.00%
Columbidae	*Spiopelia senegalensis*	Laughing Dove	0.421 ± 0.209	97.50%
Scolopacidae	*Tringa. hypoleucos*	Common Sandpiper	0.342 ± 0.241	98.20%
Cisticolidae	*Prinia inornata*	Plain Prinia	0.328 ± 0.234	97.90%
Alaudidae	*Galerida cristata*	Crested Lark	0.324 ± 0.287	98.90%
Ardeidae	*Egretta albus*	Great Egret	0.312 ± 0.143	99.90%
Accipitridae	*Accipiter virgatus*	Besra	0.268 ± 0.126/	95.00%
Passeridae	*Passer domesticus*	House Sparrow	0.231 ± 0.127	99.00%
Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	0.213 ± 0.121	98.0%
Accipitridae	*Accipiter nisus*	Eurasian Sparrow Hawk	0.172 ± 0.122	93.00%
Sylviidae	*Sylvia curruca*	Lesser Whitethroat	NA	–
Ardeidae	*Ardea cinerea*	Gray Heron	NA	–
Accipitridae	*Haliaeetus leucoryphus*	Pallas Fish Eagle (VU)	NA	–

NA = Not Analyzed due to low number of detections.

Table 3. Diversity indices of bird species in Kot Dinghano Riverine forest.

Indices	Index Values
Diversity Index	
Shannon's Diversity index	H' = 3.212
Simpson's Diversity Index	D = 15.26
Richness Index	
Margalef's Richness index R	R_1 = 5.978
Evenness Index	
Pielou J Evenness Index	J = 0.798

Table 4. Foraging guild of avian species detected in the Kot Dinghano Riverine forest habitat.

Guild	Total No of Individuals	Percentage (%)
Insectivore	2740	27.60
Carnivore/Piscivore/ Insectivore	1882	18.95
Granivore	1571	15.82
Frugivore/Insectivore	1307	13.16
Granivore/Insectivore	1191	12.00
Omnivore	867	8.73
Piscivore	271	2.73
Carnivore	65	0.65
Nectarivore/Insectivore	21	0.21
Carnivore/Insectivore	14	0.14
Total	**9929**	

found that twiggy shrubs (35.88%) and black honey shrubs (30.22%) were the most common shrubs, accounting for approximately 65.0% of the total shrub proportion. In contrast, the apple of Sodom (3.67%) and Bindii (1.14%) were the rarest shrubs in the research area. Furthermore, according to IVI, camel thorn bush was the most common weed, accounting for 10.98% of the total, whereas bitter apple (0.74%) was a rare weed that only covered a small portion of the research area. Similarly, giant cordgrass had the greatest index value, accounting for 33.16% of the ground cover, while Kapok Bush was the least prevalent, accounting for just 1.59% of the ground vegetation (Table 5 and Figure 6-9). Overall, the results of the IVI test demonstrated that riverine forests have a diverse range of floral species compositions and structures.

5. Discussions

Riverine forests are at the verge of preservation and protection due to the reliance of the population of local communities. These forests are experiencing elevated deforestation due to conversion to an agricultural field and human habitation (Fernandez-Juricic, 2004). The avian population structure has been seriously impacted by uncontrolled deforestation and degradation (Beier et al., 2002). Many forest-dependent bird species have been reported to be vulnerable or endangered as a result of habitat loss and degradation (Watson et al., 2004; Wright and Muller-Landau, 2006).

The presence of 57 bird species in the Kot Dinghano Riverine Forest demonstrated that it is a suitable habitat for a wide range of bird species to live and breed. This might be due to the abundance of food supplies in the riverine forest, such as grains, invertebrates (insects, worms), amphibians, reptiles, fishes, and small mammals, which met their needs (Rajpar and Zakaria, 2012). Furthermore, the findings revealed that bird species are habitat specialists with frequently tightly related plants. For example, *P. neglectus, P. ochruros*, and *T. caudate* were habitat specialists who frequently used the forest interior. Similarly, *P. leucotis* and *P. cafer* favored wetland habitats and forest margins dominated by shrubs (*T. tetanus* and *A. strepera*).

The higher populations of the Eurasian collard doves (*S. decaocto*), white-eared bulbuls (*P. leucotis*), common babblers (*T. caudate*) and gray francolin (*F. pondicerianus*) were recorded in riverine forest habitats. These bird species are less shy species with humans and plenty of food resources, i.e. diversity of grains, insects and fruits of shrubs that are major diet for these bird species. In addition, adjacent agriculture fields are also provided suitable habitats, rich in food grains and attractive to wide variety of insects. In contrast, lowest population was detected for lesser whitethroats (*S. curruca*), gray herons (*A. cinerea*) and Pallas fish eagle (*H. leucoryphus*). The reason was that, lesser whitethroat was migrant bird species; grey heron only utilized the waterlogged and wetland areas especially during flood season and Pallas fish eagle is vagrant in nature and always keep changes their location.

The results of foraging guilds revealed that foraging behavior varies greatly among bird species. Some species, such as fantails, flycatchers, and martins, were arboreal foragers (caught their prey on the wing by sallying in the air and tree canopy), whereas others were ambushed foragers (catch and kill their prey immediately; herons, egrets, and cormorant). Similarly, some bird species have been cryptic foragers, i.e., besra, eagles, and hawks, while others were solitary foragers, often hide in the bushes and shrubs to catch their prey; francolin, prinias, and warblers. However, some species were diving foragers, i.e., catch their prey while diving; grebes and cormorants, gregarious and social foragers (often concentrated where prey items occur in sufficient numbers; babblers, sparrows, bulbuls, and doves), and social dabbling foragers (often concentrated where prey items occur in sufficient numbers; babblers, sparrows, bulbuls, and doves), and social dabbling for (often forager on the surface of water in flocks on aquatic plants; ducks). Furthermore, several species were mud probers (probing in mud to obtain insects and invertebrates concealed in muck or soft soil; sandpipers, shanks, stilts, etc.) and nectar feeders, frequently nip the flower's nectar; sunbirds.

It was observed that the partridges, doves, babblers, and larks benefited from the ground vegetation, which was dominated by grasses and weeds. The partridges were

Table 5. Vegetation structure and composition with importance value index.

Family	Scientific Name	Common Name	IVI (Importance Value Index)
Trees			
Fabaceae	*Acacia nilotica*	Gum Arabic Tree	23.91
Fabaceae	*Prosopis cineraria*	Jand	17.64
Rhamnaceae	*Ziziphus mauritiana*	Indian Jujube	14.85
Tamricaceae	*Tamarix aphylla*	Athel Tree	14.98
Salicaceae	*Populus euphratica*	Bahan	14.39
Minmosaceae	*Acacia modesta*	Phulai	11.85
Salicaceae	*Salix tertrasperma*	Willow	2.38
Shrubs			
Tamricaceae	*Tamarix dioica*	Ghaz or Twiggy Shrub	35.88
Phyllanthaceae	*Phyllanthus reticulatus*	Black Honey Shrub	30.32
Poaceae	*Saccharum spontaneum*	Wild Sugar Cane	14.95
Capparaceae	*Capparis decidua*	Karira	13.04
Apocynaceae	*Calotropis procera*	Apple of Sodom	3.67
Zygophyllaceae	*Tribulus terrestris*	Bindii	1.14
Weed			
Rhamnaceae	*Alhaji maurorum*	Camelthorn Bush	11.98
Verbenaceae	*Phyla nodiflora*	Tangle Frogfruit	10.96
Solanaceae	*Solanum surattense*	Yellow Fruit Nightshade	9.83
Asteraceae	*Launaea procumbens*	Creeping Launaea	6.32
Boraginaceae	*Heliotropium sp*	Indian Helitrope	6.26
Asteraceae	*Sonchus asper*	Spiny Swothistle	6.25
Amaranthaceae	*Chenopodium album*	Pig Weed	3.69
Polygonaceae	*Polygonum plebeium*	Knot Weed	3.21
Phyllanthaceae	*Phyllanthus sp*	Black Catnip	2.68
Euphorbiaceae	*Euphorbia prostrata*	Prostrate Sandmat	1.69
Solanaceae	*Solanum nigrum*	Black Nightshade	1.50
Asteraceae	*Eclipta alba*	False Daisy	1.12
Cucurbitaceae	*Citrullus colocynthis*	Bitter Apple	0.74
Grasses			
Poaceae	*Desmostachya bipinnata*	Big Caordgrass	33.16
Poaceae	*Cynodon dactylon*	Scutch Grass	17.72
Amaranthaceae	*Amaranthus viridis*	Slender Amaranth	5.73
Cypraceae	*Cyperus sp*	Nut Grass	4.68
Amaranthaceae	*Aerva javanica*	Kapok Bush	1.59

found to be a sensitive and bashful species with a secretive demeanor. Anthropogenic activities such as habitat loss and degradation due to deforestation, unregulated grazing, and fuel wood collections easily disturb bird species. Seeds of herbaceous flora, acorns, legumes, and grains were foraged by doves and partridges. Bulbul also preferred to consume the fruits (berries) and insects found in grasses and bushes.

Moreover, *Streptopelia decaocto* and *F. pondicerianus* chose nearby agricultural fields in pursuit of food, refuge, and reproduction. The partridges were seen using scrub vegetation and brush-lined water channels for cover and grassy places for nesting. This might be because these isolated floral patches control heat, give shade, and provide protection from predators and harsh weather. The ecological significance of bird species, on the other

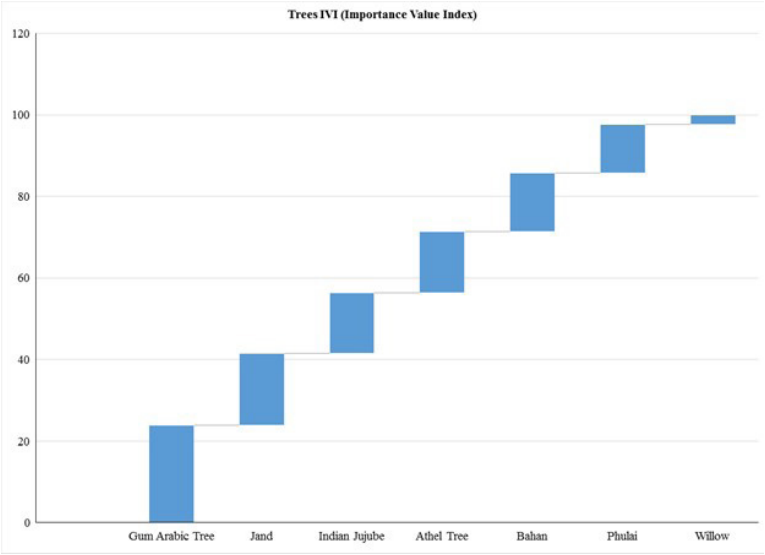

Figure 6. Importance value index of tree species of riverine forest habitat.

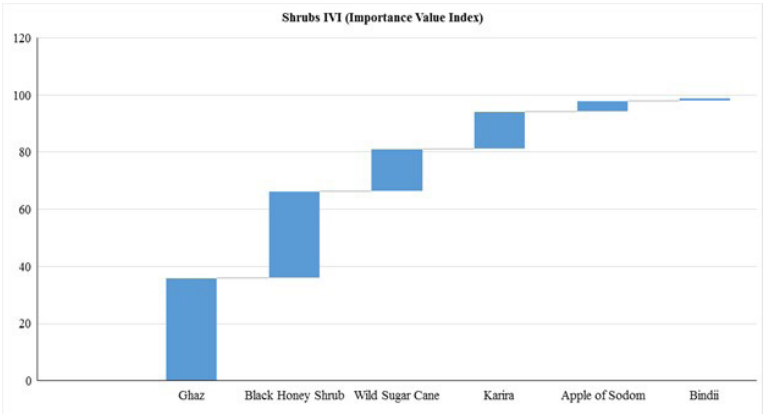

Figure 7. Importance value index of shrub species in riverine forest habitat.

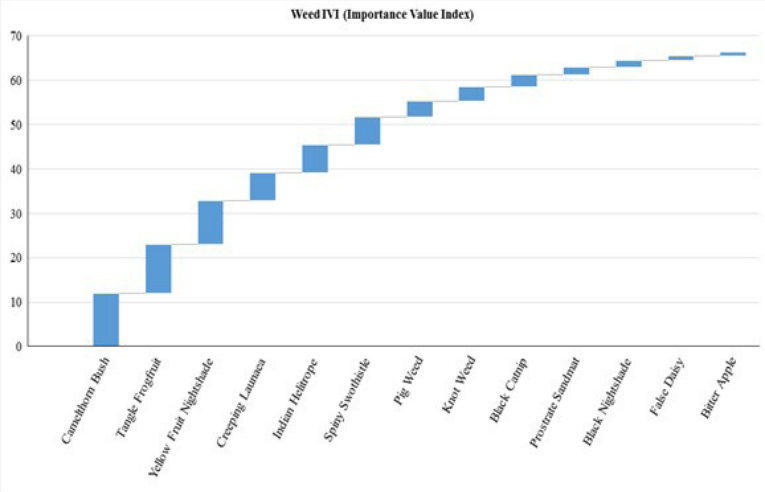

Figure 8. Importance value index of weed species of riverine forest habitat.

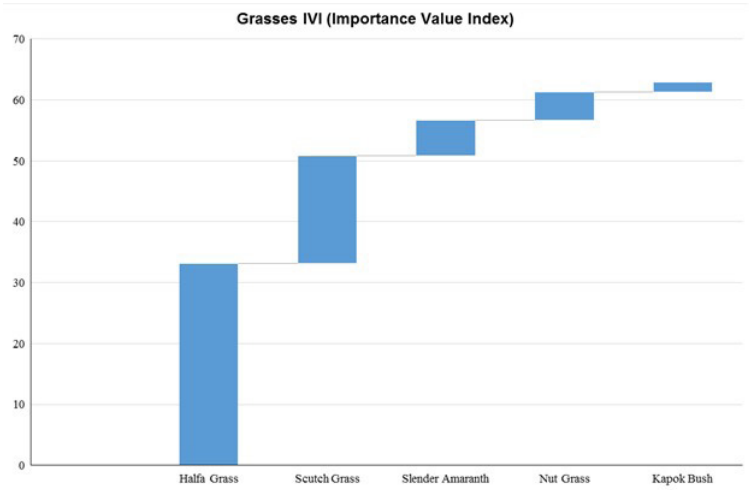

Figure 9. Importance value index of grass species of riverine forest habitat.

hand, may differ from species to species. Floral structures and compositions are major driving factors influencing habitat selection, food resource utilization, shelter, and breeding grounds for a variety of bird species. It has also been demonstrated that floral species composition, food availability, and climatic factors, such as temperature and relative humidity, impact bird relative abundance and dispersion (Mengesha and Bekele, 2008; McCain, 2009; Girma et al., 2017).

In all, 32 floral species were recorded from the riverine forest habitat, including trees (eight species), shrubs (six species), weeds (thirteen species), and grasses (five species). The IVI value revealed the riverine forest's ecological relevance, i.e., ecological advantages at several nested scales ranging from habitat to ecoregion and dominating floral species composition that suggest the capacity to maintain biodiversity. Furthermore, riverine forests may provide reliable data to help biodiversity protection and conservation methods.

Fuelwood collection and unrestricted grazing by livestock have put a strain on habitat production and breeding success of partridges, warblers, grass birds, and larks in the Kot Dinghano riverine forest, according to direct observation. Furthermore, encroachment, i.e., agricultural growth, places a strain on this riverine forest, which might result in habitat loss and degradation, significantly impacting the population of many bird species. Partridge populations in the Kot Dinghano Riverine forest have declined by more than 50%, according to local communities, due to illegal hunting within adjacent agricultural habitats, heavy pesticide use, uncontrolled grazing by livestock, and human occurrence in breeding areas for the purposes of fuel wood, fodder, and honey collection, as well as incidence fire during honey collection.

6. Conclusions

Based on the results, it is concluded that the Kot Dinghano Riverine Forest is a highly productive and attractive habitat for a diverse range of bird species to meet their needs. Unfortunately, due to human meddling, this ecosystem is under a variety of threats and is rapidly deteriorating. As a result, it is strongly recommended that this crucially important riverine forest habitat be a conserved priority basis to improve the bird population.

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