

Effects of invasive alien plants and habitat structure on bird assemblages in a unique lowland forest in eastern Nepal

Binod BHATTARAI¹, Dipendra ADHIKARI^{4#}, Jagan Nath ADHIKARI^{2,3}
& Bishnu Prasad BHATTARAI^{1,3*}

Received: May 15, 2024 – Revised: September 21, 2024 – Accepted: September 23, 2024



Bhattacharai, B., Adhikari, D., Adhikari, J. N. & Bhattacharai, B. P. 2024 Effects of invasive alien plants and habitat structure on bird assemblages in a unique lowland forest in eastern Nepal. – *Ornis Hungarica* 32(2): 1–25. DOI: 10.2478/orhu-2024-0019

Abstract Invasive alien species play a major role in biodiversity decline. We studied the impacts of invasive alien plant species (IAPS) on bird assemblages and their habitats in Jalthal Forest, a biogeographically unique lowland remnant forest in eastern Nepal. We surveyed birds by point counts and quantified environmental variables at 89 sites. Observations of 1,373 individuals of 86 species showed that species richness was the highest in wooded grasslands and floodplains and lowest in sal forests invaded by IAPS, whereas abundance was highest in IAPS-invaded forests. Abundance and richness decreased with increasing cover of IAPS, shrub cover and distance to water. The abundance and richness of every feeding guild except omnivores were negatively correlated with IAPS cover. Our results increase our understanding of the impacts of IAPS on birds and clearly indicate the need of controlling IAPS in Jalthal Forest, and thus, are valuable for forest management and biodiversity conservation.

Keywords: biodiversity, bird diversity, conservation, invasive plant species, tropical forest

Összefoglalás Az idegenhonos inváziós fajok jelentős szerepet játszanak a biológiai sokféleség fogyatkozásában. Jelen vizsgálatban az idegenhonos inváziós növényfajok (IIN) madáregyüttesekre és élőhelyeikre gyakorolt hatását tanulmányoztuk a Jalthal-erdőben, amely egy biogeográfiai szempontból egyedülálló alföldi maradványerdő Kelet-Nepálban. A madarakat pontszámlálással mértük fel, és a környezeti változókat számszerűsítettük 89 mintavételi helyszínen. 86 faj 1373 egyedének megfigyelése alapján a fajgazdagság a fás gyepeken és ártereken volt a legmagasabb és az IIN által előzőnlött szálafa-erdőkben volt a legalacsonyabb, míg az abundancia az IIN által előzőnlött erdőkben volt a legmagasabb. Az abundancia és a fajgazdagság csökkent az IIN borítottság, a cserjeborítás és a víztől való távolság növekedésével. A mindenevők kivételével az összes táplálkozási guild abundanciája és fajgazdagsága negatívan korrelált az IIN borítottsággal. Eredményeink hozzájárulnak az IIN fajok által a madarakra gyakorolt hatások megértéséhez, és világosan jelzik az IIN fajok gyérítésének szükségességét a Jalthal-erdőben, így módon értékesek az erdőgazdálkodás és a biológiai sokféleség megőrzése szempontjából.

Kulcsszavak: biodiverzitás, madarak sokfélesége, természetvédelem, inváziós növényfajok, trópusi erdők

¹ Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kirtipur, Kathmandu, Nepal

² Department of Zoology, Birendra Multiple Campus, Tribhuvan University, Chitwan, Nepal

³ Nepal Zoological Society, Kathmandu, Nepal

⁴ Nepal Conservation and Research Center, Chitwan Nepal

* corresponding author; e-mail: bpbhattacharai@cdztu.edu.np / bishnu.bhattacharai@cdz.tu.edu.np

Dipendra Adhikari is deceased. The authors dedicate this paper in memory of the Late Dipendra Adhikari.

Introduction

Invasive alien species (IAS) are species established or introduced outside of their natural geographic range, which can successfully expand their range and harm biodiversity, economy, and human health (Davis *et al.* 2001). Invasive alien plant species (IAPS) are considered to have a major pressure on the current state of biodiversity globally (Butchart *et al.* 2010). IAPS destruct or alter the habitats where they are introduced (Weidlich *et al.* 2020), and often cause a cascade effect on the food web (Gan *et al.* 2009), therefore, the effects of invasion are not limited to a single trophic level.

Mikania micrantha and *Chromolaena odorata* are some of the world's most problematic IAPS (Weber 1960). Both species are native to Central and South America (Holm *et al.* 1977, Gautier 1992). In Nepal, *Ch. odorata* and *M. micrantha* was first reported in 1956 and in 1963, respectively (Shrestha & Shrestha 2021). With the latest addition of the invasive plant *Mimosa diplotricha* (Sharma *et al.* 2020), currently, there are 27 identified invasive plant species in Nepal, but the number of vascular alien plant species found in natural habitats is 183 (Shrestha 2019) and the number of alien animal species is 64 (Budha 2015). Four of these species (*Ch. odorata*, *Eichhornia crassipes*, *Lantana camara*, *M. micrantha*) are among the 100 most problematic IAPS in the world (Lowe *et al.* 2000). Invasive Alien Plant Species (IAPS) in Nepal are primarily found in the Tarai, Siwalik, and Mid-hill regions, which have similar climatic conditions to tropical and subtropical locations around the world (Shrestha 2016). Because tropical and subtropical areas are more vulnerable to IAPS invasions (Bhattarai *et al.* 2014, Shrestha 2016), it stands to reason that these parts of Nepal are also more likely to be invaded by such species.

The ability to propagate by roots, stem segments, and easily spreadable seeds helps *Ch. odorata* and *M. micrantha* to spread successfully and rapidly (Zachariades *et al.* 2009, Day *et al.* 2016). With the establishment of IAPS, the composition of the vegetation changes, and the structure of habitats also often changes in parallel, because vegetation plays a major role in defining habitat structure. For example, thickening of bushes is a change in habitat structure (Aleixo 1999), which may influence biodiversity and ecological processes (Seymour & Dean 2010). Since successfully established IAPS are known to alter the structure of habitats (Pearson 2009, Aravind *et al.* 2010), IAPS are also expected to influence the relationship between the richness of bird assemblages and habitat structure.

IAPS are expected to affect the bird diversity either positively by offering new habitat and increasing prey availability (Gan *et al.* 2009) or negatively by altering suitable habitat and decreasing prey availability (Pearson 2009, Aravind *et al.* 2010, Kessler *et al.* 2011). Nepal is known to host 892 species of birds, which accounts for 8.9% of the global species richness of birds (Grimmett *et al.* 2016, BCN 2023). Of these bird species, 39 are globally threatened and 31 are near threatened. The eastern part of Nepal shows biogeographical links with the Indo-Malayan, the Palearctic, and the Sino-Japanese regions (Kandel *et al.* 2018). From Jalthal Forest in eastern Nepal, a total of 230 bird species has been recorded by Sharma *et al.* (2021), among them eight species are globally threatened, 31 are nationally threatened and one is nationally protected. However, the number of bird species in the area is expected to be around 300 (Grimmett *et al.* 2016).

The impacts of IAPS on the abundance of birds are commonly reported. IAPS have the potential to change bird habitats, to provide non-nutritious foods, and to break functional relationships with their habitats (Flanders *et al.* 2006). Previous studies indicated that vegetation structure affects the birds' selectivity of their habitats (Karr & Roth 1971, Yahner 1982, Robinson & Holmes 1984, Dinanti *et al.* 2018). Insectivorous birds such as the Asian Green Bee-eater (*Merops orientalis*), Common Hawk-cuckoo (*Hierococcyx varius*), Large Cuckooshrike (*Coracina macei*), Black Drongo (*Dicrurus macrocercus*) and Spangled Drongo (*D. hottentottus*) are inhibited in their movement, flight, and insect capturing efficiency by the thick vegetation layer produced by many invasive species, for example, *Lantana camara* (Aravind *et al.* 2010). Frugivores are negatively affected if the fruit production of native plants is compromised due to the IAPS invasion (Mangachena & Geerts 2017), but are positively affected if the invasive species provides nutritious and abundant fruits (Ramaswami *et al.* 2019). The low abundance or absence of songbirds, water birds, and breeding birds in invaded habitats can be due to the dense vegetation of IAPS blocking the access of birds to the ground vegetation and ground surface, where birds thus are unable to forage, and hence will avoid invaded habitats (Gan *et al.* 2009). However, the IAPS in many areas can also increase habitat diversity, providing nesting and foraging sites for some bird species. Hence, the abundance of species can be high in invaded areas, but as a whole, species richness and diversity may be low (Flanders *et al.* 2006, Wilcox & Beck 2007, Gan *et al.* 2009, Aravind *et al.* 2010, Keller & Avery 2014).

Jalthal Forest is a unique forest in the southeastern part of Nepal and is highly disturbed by locals and invaded by IAPS (GGN 2021). The forest is notable as the largest remaining forest island in the Terai region of Nepal, featuring a unique mix of tropical and subtropical tree species (Sharma 2020). Hence, this forest offers a good opportunity to study the impacts of IAPS on the diversity of birds. In addition, forest management needs to know the effect of IAPS on the biodiversity of the forest to develop effective conservation management for this forest. Because birds are important indicators of biodiversity, this study aimed to (i) assess the richness, breeding status and conservation status of the birds of Jalthal, (ii) evaluate the effect of IAPS on the bird assemblages, (iii) test relationships between bird diversity or abundance and environmental variables.

Material and Methods

Study area

Jalthal Forest is in the far east lowland of Nepal (87°55' and 88°03'E, 26°27' and 26°32'N) and extends to 63 km² in area and between 60 and 120 m in elevation. The forest has a tropical monsoon climate (Figure 1). According to the nearest weather station (Chandragadhi, station No 1412), the mean annual temperature is 25 °C and total annual precipitation is 2,300 mm (DHM 2019).

This forest is surrounded by the human settlements of Haldibari Rural Municipality in the north, Barhadashi Rural Municipality in the west, Kachankawal Rural Municipality (lowest

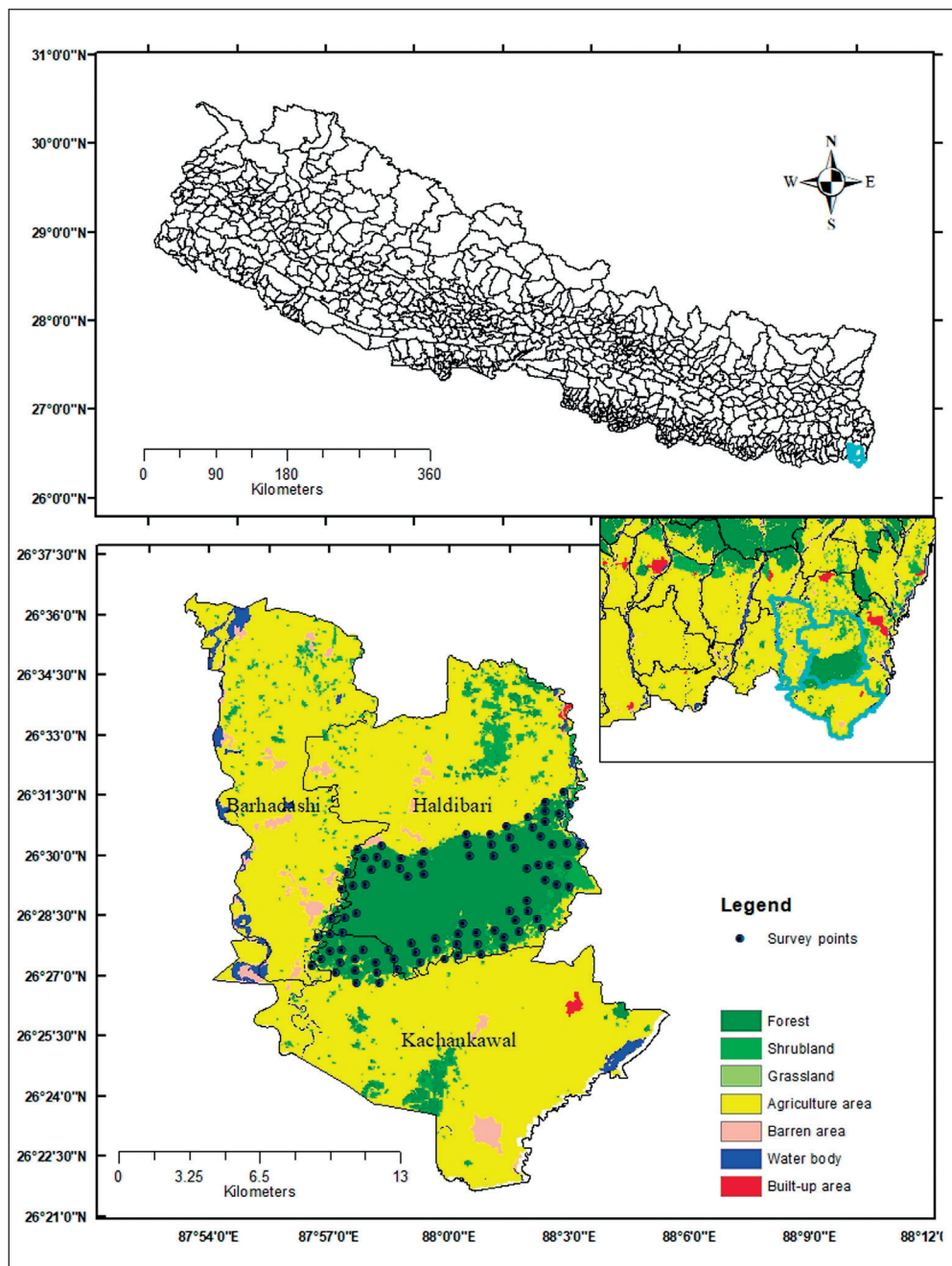


Figure 1. Map of the study area with the point count stations
 1. ábra A vizsgálati terület térképe a számlálási pontokkal

altitude of Nepal) in the south, and Bhadrapur Municipality in the east. The forest is drained by Bhutani Khola to the western side, and Deonia Khola to the eastern side. This forest has 22 community forest user groups.

This forest contains unique and diverse plant species of tropical and subtropical regions. The forest is the one and only remnant tropical forest in the eastern Tarai region of Nepal, and sal (*Shorea robusta*) is the dominant tree species (Sharma 2018).

Data collection

We collected data in one field visit conducted in January 2020. We surveyed birds by using the point count method (Laiolo 2002). We first selected survey points on the edge of the forest with the help of Google Earth Pro. Then, we selected two survey points, one was 500 m from the edge and the second was 1,000 m from the edge towards the centre of the forest. We surveyed a total of 89 points in the 1-km-wide edge of the forest. Areas closer to the centre (interior) were not surveyed due mainly to risks of encountering wild elephants or wild boars inside the forest. The coordinates of each point count station were recorded by a GPS unit (Garmin eTrex 10).

Birds were recorded in point count stations from 7:00 A.M to 11:00 A.M and 14:00 P.M to 17:00 P.M. Usually, most of the birds are active in the morning and evening. However, because the birds were less active in early morning and late afternoon on foggy morning and cold windy evenings in winter (Robbins 1981), we sampled birds until late morning and started counting in the early afternoon. We recorded all birds that were seen within a circle of 50 m radius around the point count stations in 20 minutes (Wilcox & Beck 2007). High flying birds which crossed the point were ignored. We observed birds by using binoculars (Bushnell 20 X 50) and identified them by using a field guide (Grimmett *et al.* 2016). The calls of the birds were also recorded with a cell phone in MP3 format, and we then compared these sounds using the bird song database of Xeno-Canto (<https://www.xeno-canto.org/>). We also identified birds to the species level by comparing photographs taken in the field (Nikon D3400, 75–300 mm) with field guide images (Grimmett *et al.* 2016).

Vegetation sampling

To characterise vegetation, we recorded the visually estimated percentages of tree canopy cover (T_{cc}) and shrub cover (S_{cc}) (0–100% each), and IAPS cover class (5%, 20%, 50%, 75%, 100%) in a circle of 10 m radius around each point count station. We also recorded disturbance indicators such as distance to the nearest motorable road (Dr) and distance to the nearest water source (Dw). The combination of dominant plant species, the number of large trees (Ltn), and nearby water sources (Dw) were also noted and later used in habitat classification.

Data analysis

We first prepared Rank Abundance Curves (RAC) to show relative species abundances following Pandey *et al.* (2020) by plotting the relative abundances of species on the Y axis

Table 1. Details of the studied habitat types
 1. táblázat A vizsgált élőhelytípusok részletei

S.N.	Habitat type	Codes	Details of habitat
1	Sal forest	Sf	Dominant Sal tree and IAPS cover less than 25%
2	Sal <i>Mikania</i> forest	Sm	Dominant Sal tree with invasive <i>Mikania</i> Cover >25
3	Sal <i>Chromolaena</i>	Sc	Dominant Sal tree with invasive <i>Chromolaena</i> Cover >25
4	Invaded scrub	Is	Shrubland invaded by IAPS with very few trees
5	Flood plain	Fp	Side of flowing stream/river
6	Pastureland	Pl	Regularly grazed area, presence of cattle dung
7	Mixed woodland	Mw	Forest not dominated by any species
8	Wooded grassland	Wg	Open grassland with less than 25% shrub with trees number less than 5 per ha

and the abundance rank of species on the X axis. We used the Shannon-Wiener and the Shannon indices to characterise diversity. We built Generalized Linear Models (GLMs) to test the relationships between the diversity or abundance of birds and environmental variables. The GLMs were fitted with normal distribution and identity link function. We repeated the GLMs to assess the effects of environmental variables on the abundances of four bird feeding guilds (Herbivore, Carnivore, Insectivore, Omnivore). Rather than include all of the predictors in one model, we chose to fit each predictor separately because it allows us to perform responsible pairwise comparisons between log-ranks. This model also avoids the potential issues of multicollinearity, and shows that individual effect of a single variable on the response is actually correct. This approach also provides a clearer insight into the role of each predictor on abundance and richness separately, making sure that contributions are not masked or confounded by other factors (Burnham & Anderson 2002, Zuur *et al.* 2010).

We also studied the association of different guilds of birds to the different habitat types by using Canonical Correspondence Analysis (CCA) in Canoco v 4.5 (ter Braak & Smilauer 2002). The habitat types (*Table 1*) were classified as in Aravind *et al.* (2010) and Bergner *et al.* (2015). Pastureland, floodplains, and invaded scrub were not included in the analysis since these were present at fewer than four point count stations. The vertical strata of the forest were classified as in Rocha *et al.* (2015).

All univariate and multivariate analyses were performed by the use of different statistical software, PAST v 4.03, and MS-Excel 2016. The coordinates of the point count station were processed in ArcGIS 10.8 (ESRI 2019) to prepare the map of the study area.

Results

Richness, breeding status and conservation status

A total of 1,373 individuals of birds from 15 orders, 40 families, and 86 species were identified. The most abundant order was Passeriformes with 20 families (*Figure 2*). The most abundant families were Dicruridae and Sturnidae with five species each followed

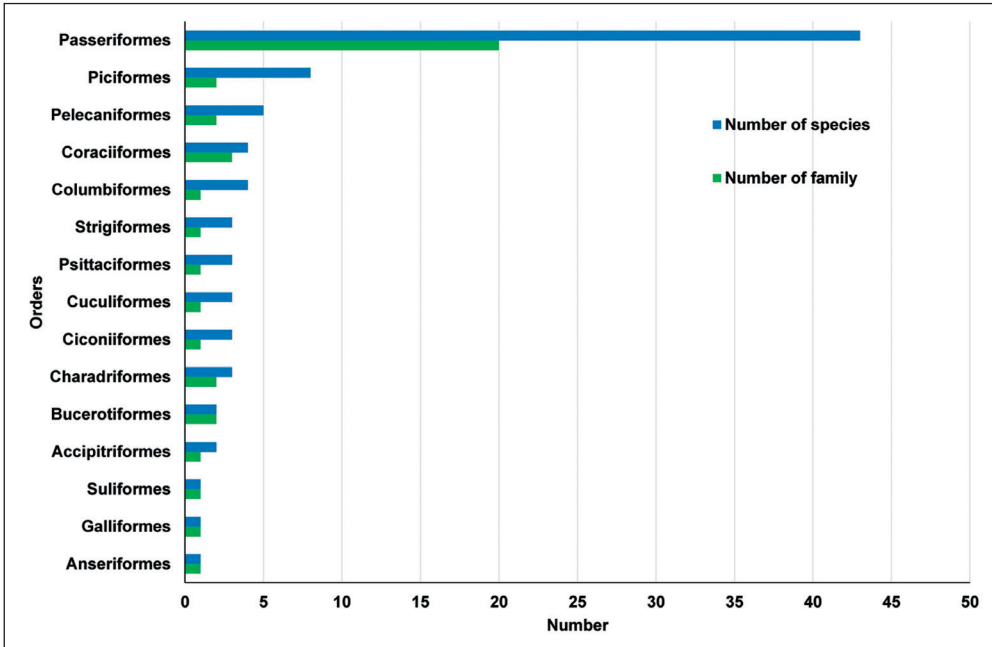


Figure 2. Numbers of families and species in each order

2. ábra Az észlelt családok és fajok száma a rendeken belül

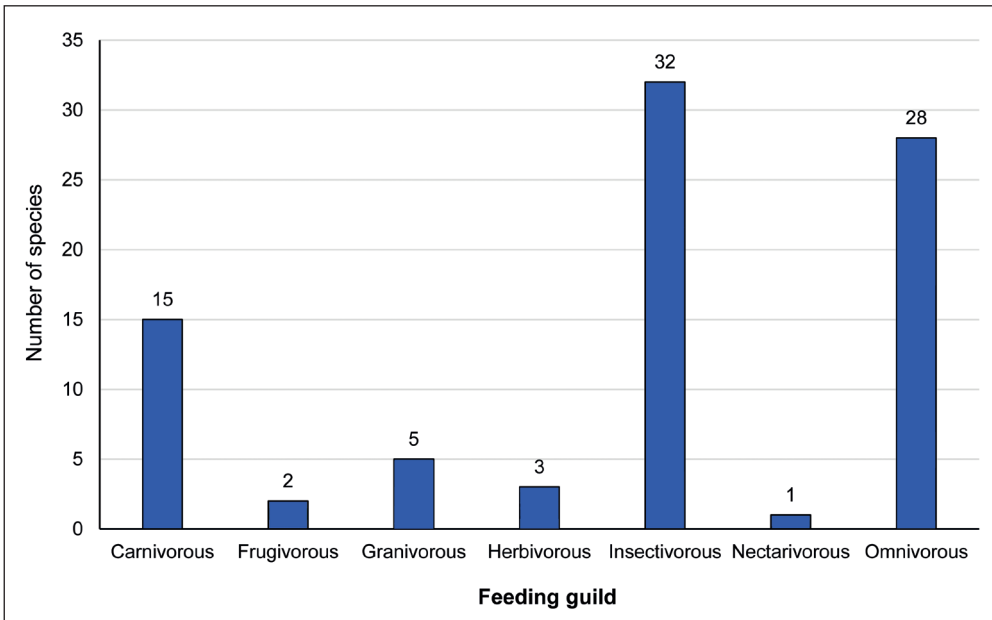


Figure 3. Number of species by feeding guild

3. ábra Fajok száma táplálkozási guildenként

by Ardeidae, Picidae, Columbidae, Motacillidae, and Muscicapidae with four species each. Wooded grasslands had the highest species richness (mean 8.2 ± 0.83) followed by floodplains (average 7.4 ± 1.67) and the lowest species richness was found in sal forests invaded by *Chromolaena* (average 3.78 ± 1.67).

Among the recorded species, 74 species were resident, 10 species were winter visitor, and one passage and summer visitor species were also recorded. Insectivorous birds were the most species-rich guild (32 species) and frugivores were the least species-rich (2 species) (Figure 3). We observed three Near Threatened (NT) birds: Lesser Adjutant (*Leptoptilos javanicus*) (Figure 4A), Asian Woollyneck (*Ciconia episcopus*) (Figure 4B) and Alexandrine Parakeet (*Psittacula eupatria*) (Figure 4C). Likewise, two nationally vulnerable species – Lesser Adjutant and Black Stork (*Ciconia nigra*) (Figure 4D) and four nationally near threatened species – Asian Woollyneck, Oriental Pied Hornbill



Figure 4. Bird rarities observed in Jalthal Forest, A. Lesser Adjutant (*Leptoptilos javanicus*) (Globally Near Threatened and Nationally Vulnerable), B. Asian Woolly-necked Stork (*Ciconia episcopus*) (Globally and nationally Near Threatened), C. Alexandrine Parakeet (*Psittacula eupatria*) (Globally and nationally Near Threatened), D. Black Stork (*Ciconia nigra*) (Globally Least Concerned and nationally Vulnerable)

4. ábra A Jalthal erdőben észlelt madár ritkaságok. A. Indiai marabu (*Leptoptilos javanicus*) (globálisan mérsékelten fenyegetett, nemzeti szinten sebezhető), B. Ázsiai gyapjasnyakú gólya (*Ciconia episcopus*) (globálisan és nemzeti szinten mérsékelten fenyegetett), C. Nagy Sándor-papagáj (*Psittacula eupatria*) (globálisan és nemzeti szinten mérsékelten fenyegetett), D. Fekete gólya (*Ciconia nigra*) (globálisan nem fenyegetett, nemzeti szinten sebezhető)

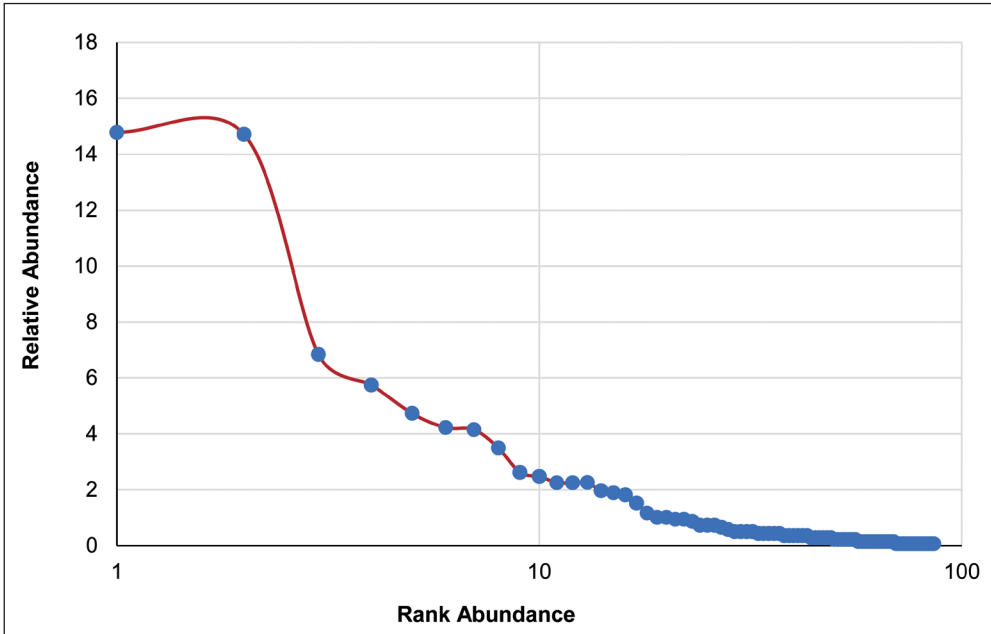


Figure 5. Rank abundance curve of bird species recorded
5. ábra Rang-abundancia görbe az észlelt fajok alapján

(*Anthracoceros albirostris*), Indian Peafowl (*Pavo cristatus*) and Alexandrine Parakeet were observed during the field study.

The RAC showed a steep decrease along the Y-axis and a gradual decline along the X-axis (Figure 5).

Bird diversity

The highest value of the Shannon-Wiener index (H) was in wooded grasslands followed by floodplains and the lowest value was in mixed woodlands. The highest evenness value was in mixed woodland and the lowest was in floodplains. The highest abundance of birds was recorded

Table 2. Bird species richness and diversity indices per habitat type
2. táblázat Madár fajgazdagság és diverzitási indexek élőhelytípusonként

Diversity measures	Habitat types							
	Wg	Sm	Sc	Sf	Mw	Fp	Is	PI
Abundance	115.00	470.00	150.00	275.00	182.00	128.00	32.00	21.00
Species richness total	29.00±3.07	47.00±13.54	24.00±4.13	37.00±7.89	33.00±5.89	30.00±4.05	9.00±1.39	6.00±1.27
Species richness per plot	8.2±0.83	4.83±1.8	3.7±1.6	4.9±2.09	5.7±3.2	7.4±1.6	1.4±1.14	4±0.0
Shannon_H	1.99±0.11	1.40±0.35	1.18±0.50	1.41±0.44	0.12±0.07	1.78±0.11	1.52±0.18	1.35±0.02
Evenness	0.91±0.05	0.92±0.08	0.96±0.04	0.94±0.8	1.50±0.3	0.83±0.12	0.96±0.04	0.97±0.02

in the Mikania invaded sal forest with a mean abundance of 47.0 ± 13.54 birds per plot, whereas the lowest abundance was in pastureland with a mean of 10.5 ± 1.27 birds per plot (*Table 2*).

Relation of abundance and species richness with environmental variables

The Generalized Linear Model (GLM) showed that both overall abundance and species richness decreased with increasing cover of IAPS, shrub cover and distance to the nearest water source (*Table 3*). The abundance of birds also decreased with the increasing distance to the nearest motorable road (*Table 3*).

Effects of environmental variables on different feeding guilds of birds

Table 3. Summary of results of generalized linear models testing the effects of environmental variables on bird abundance and species richness (bold letters indicate significant results)

3. táblázat A környezeti változók által a madarak abundanciájára és fajgazdagságára gyakorolt hatásokat tesztelő általánosított lineáris modellek eredményeinek összefoglalása

Environmental variables	Abundance			Richness		
	Slope a	Intercept b	p-value	Slope a	Intercept b	p-value
Distance to nearest water source	-0.006	19.288	0.012	-0.001	6.437	0.014
Distance to nearest motorable road	-0.004	19.453	0.034	-0.0009	6.408	0.061
Cover of IAPS	-0.149	23.98	<0.001	-0.054	8.488	<0.001
Tree canopy cover	0.001	16.428	0.975	0.008	5.361	0.415
Shrub cover	-0.110	21.983	0.002	-0.052	8.325	<0.001
Numbers of large trees	0.204	15.322	0.525	0.110	5.103	0.177

Generalized Linear Models (GLM) carried out to assess the effects of environmental variables on four feeding guilds of birds (Herbivore, Carnivore, Insectivore and Omnivore) showed that the distance to the nearest water source positively influenced the richness of Herbivores, Insectivores and Omnivores (*Table 4*). Distance to the nearest road positively influenced the richness of Omnivores and negatively influenced the abundance of Carnivores, Insectivores and Omnivores (*Table 4*). Tree canopy cover positively influenced the richness and abundance of Herbivores and negatively influenced the richness of Carnivores (*Table 4*). Shrub cover had a positive effect on the richness and abundance of Carnivores, and a negative effect on the richness of Insectivores (*Table 4*). Other variables did not have significant effects on neither the richness nor the abundance of feeding guilds.

Relationship between the cover of invasive alien plant species and bird species

Altogether, ten abundant species were taken to test whether there is any significant difference between the abundance of different feeding guild in the different cover class of IAPS. There was a significant difference between the abundance of different feeding guilds in different cover classes ($\chi^2=54.71$, $p<0.00001$). The abundance and richness of herbivorous species were

Table 4. Results of generalized linear models with normal distribution and identity link function test showing the effects of different environmental variables on the richness and abundance of birds belonging to different feeding guilds in Jalthal forest

4. táblázat A különböző környezeti változók által a különböző táplálkozási guildekbe tartozó madarak fajgazdagságára és abundanciájára gyakorolt hatások tesztelésére alkotott általánosított lineáris modellek eredményei

Feeding Guild	Environmental variables	Response variables					
		Richness			Abundance		
		Estimate	t-value	p-value	Estimate	t-value	p-value
Herbivore	Intercept	3.13	1.54	0.120	1.5	5.65	<0.0000
	Dw	0.005	3.32	0.001	-0.0002	-0.98	0.32
	Dr	-0.001	-1.60	0.112	-0.000	-0.18	0.85
	T_cc	0.064	2.43	0.017	0.007	1.86	0.049
	S_cc	0.002	0.09	0.927	-0.0004	-0.12	0.90
	Ltn	-0.055	-0.24	0.810	-0.039	-1.24	0.21
	Cav	-0.44	-1.03	0.304	-0.039	-0.66	0.51
Carnivore	Intercept	2.077	1.069	0.296	0.693	1.17	0.252
	Dw	-0.0006	-0.311	0.758	0.0004	0.72	0.47
	Dr	0.0015	1.183	0.249	-0.0009	-2.69	0.01
	T_cc	-0.1005	-3.607	0.001	-0.004	-0.635	0.53
	S_cc	0.077	2.765	0.011	0.027	3.72	0.001
	Ltn	0.783	3.414	0.302	0.110	1.73	0.09
	Cav	-0.490	-0.869	0.394	-0.007	-0.048	0.96
Insectivore	Intercept	8.55	8.235	0.000	2.6	5.14	<0.0000
	Dw	0.003	3.83	<0.001	0.000	0.23	0.81
	Dr	0.001	1.876	0.065	-0.001	-3.13	0.002
	T_cc	-0.023	-1.397	0.167	-0.0003	-0.042	0.96
	S_cc	-0.04	-3.962	<0.001	-0.0014	-0.243	0.80
	Ltn	-0.67	-0.51	0.610	-0.019	-0.298	0.76
	Cav	0.033	0.13	0.890	-0.047	-0.408	0.68
Omnivore	Intercept	11.00	7.43	0.000	2.65	5.14	<0.0000
	Dw	0.002	1.92	0.049	0.000	0.23	0.81
	Dr	0.004	4.25	<0.001	-0.001	-3.13	0.0025
	T_cc	-0.03	-1.44	0.150	-0.0003	-0.042	0.96
	S_cc	-0.02	-1.59	0.110	-0.001	-0.24	0.80
	Ltn	0.06	0.35	0.720	-0.019	-0.29	0.76
	Cav	0.28	0.87	0.380	-0.02	-0.40	0.68

most affected by the cover of IAPS (*Table 5*). The correlation between abundance or species richness and IAPS cover class was significantly negative in every guild except for omnivorous species, although the correlation was moderate for all guilds (*Table 5, Figure 6*).

Table 5. Spearman's rank correlation coefficients and their significance between the abundance or richness of birds belonging to different feeding guilds and IAPS cover class

5. táblázat A különböző táplálkozási guildekbe tartozó madarak abundanciája vagy fajgazdagsága és az idegenhonos inváziós növényfajok borítási kategóriái között számolt Spearman-féle rang-korrelációs együtthatók és szignifikancia-értékük

Feeding Guilds	Abundance		Richness	
	r_s -value	p-value	r_s -value	p-value
Carnivorous	-0.273	0.012	-0.200	0.067
Herbivorous	-0.366	0.0007	-0.259	0.018
Insectivorous	-0.266	0.015	-0.237	0.040
Omnivorous	-0.032	0.773	-0.036	0.740
Carnivorous	-0.273	0.012	-0.200	0.067

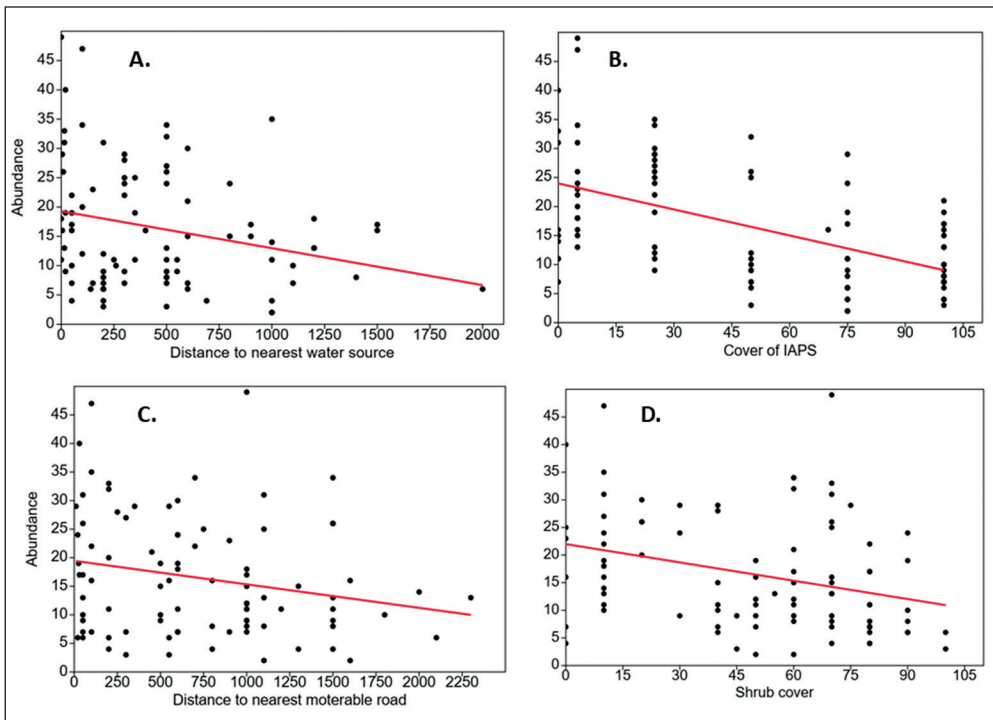


Figure 6. Relationships between bird abundance and different environmental variables: A. Distance to the nearest water source, B. Cover of IAPS, C. Distance to nearest motorable road, D. Shrub cover

6. ábra A madarak abundanciája és a környezeti változók közötti összefüggések. A. Távolság a legközelebbi vízforrástól, B. Idegenhonos inváziós növényfajok borítása, C. A legközelebbi gépjárművekkel járható út távolsága, D. Cserjeborítás

Use of vertical strata of the forest by birds

The abundance of birds was highest (32%) in the top layer of vertical strata, followed by the middle stratum (27%). The abundance of birds in the ground stratum was higher (22%) than in the lower stratum (19%). Species richness was also highest in the middle strata (33%), followed by the ground stratum (27%), and was lower in the top stratum (21%) and the lower stratum (19%).

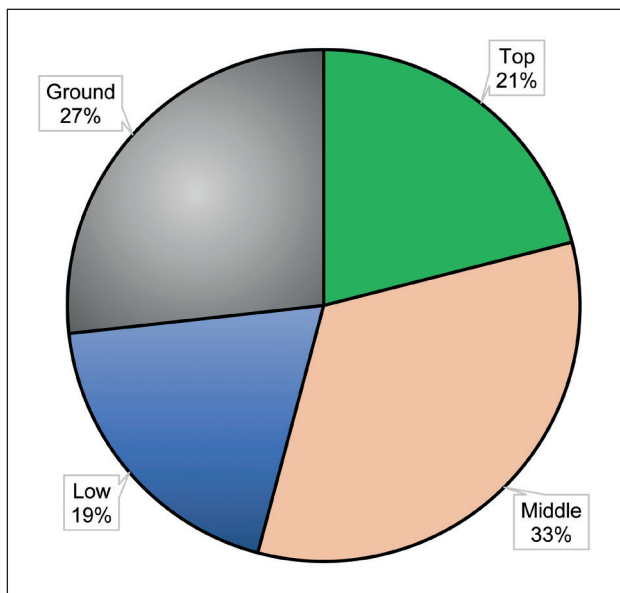


Figure 7. Species richness in each vertical stratum of trees
7. ábra Fajgazdagság vertikális eloszlása

Effects of habitat structure

The CCA followed by the Monte-Carlo permutation test of significance of all canonical axes showed significant associations with habitat type in the case of the herbivorous (Trace = 0.591, F-ratio = 1.663, $p = 0.049$) and the omnivorous guilds (Trace = 0.980, F-ratio = 1.400, $p = 0.049$), whereas there were no significant associations with habitat type in the case of the insectivorous guild (Trace = 1.871, F-ratio = 1.320, $p = 0.108$), and the carnivorous guild (Trace = 1.128, F-ratio = 1.052, $p = 0.322$) (Figure 8).

Discussion

Our study showed that Passeriformes were the most abundant and Anseriformes and Pelecaniformes had the lowest abundance, which is similar to the results found in similar habitat types in Nepal (Ghimire *et al.* 2021). Passeriformes include sparrows, tits, magpie, wagtails and other species, that usually forage in flocks and tend to remain close to agricultural fields and human settlements, where they find more foods grains. Hence, their abundance was recorded higher there. However, the observed species of Anseriformes (Lesser Whistling-duck) and Pelecaniformes (Little Cormorant) are winter visitor waterbirds mostly occurring near the stagnant water reservoir of Tarai. In Jalthal, there are no such big lakes or ponds, thus a lower abundance of waterbirds were not surprising.

There are 168 nationally threatened and 39 internationally threatened bird species in Nepal (Inskipp *et al.* 2016). We observed eight species that are globally threatened, 31 nationally threatened and one nationally protected species of birds (Shrestha 1996).

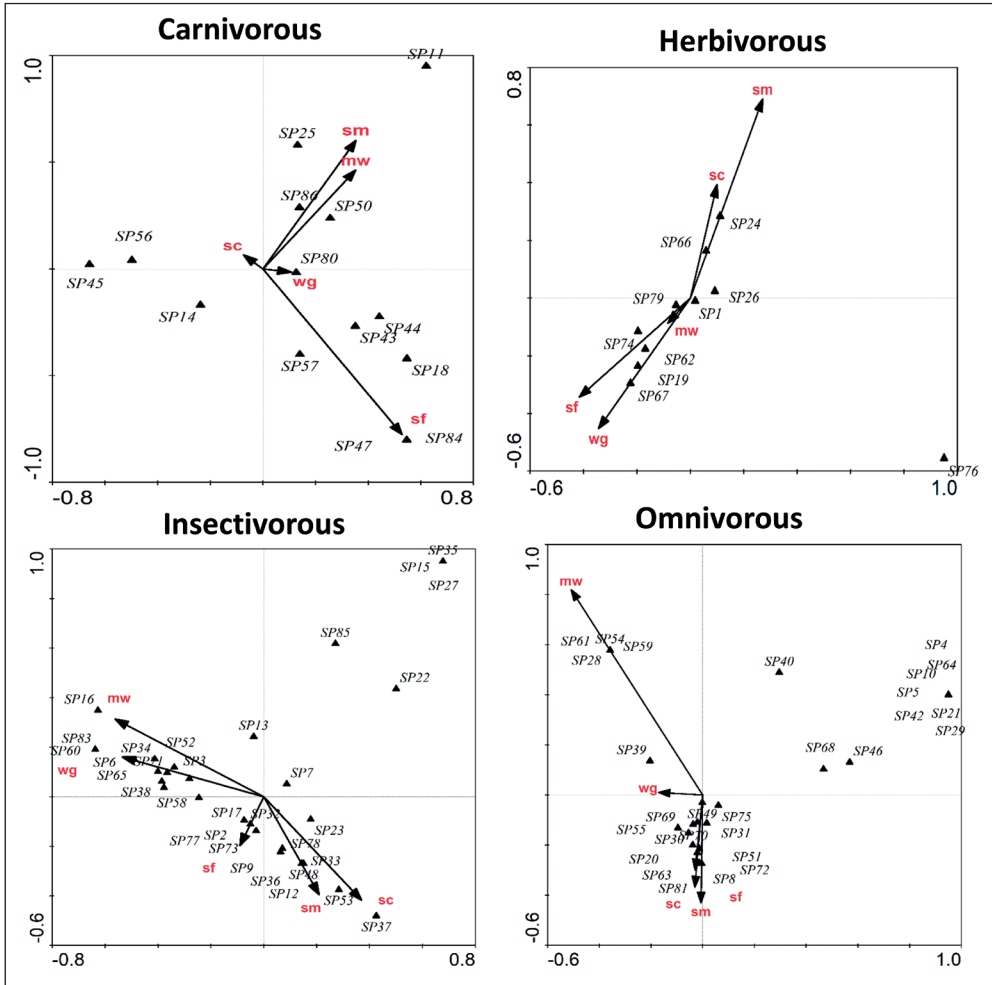


Figure 8. CCA ordination biplots showing the response of different feeding guilds to habitat types of Jalthal forest (mw: Mixed woodland, wg: Wooded grassland, sf: Sal forest, sm: Sal forest with invasive *Mikania*, sc: Sal forest with invasive *Chromolaena*). Codes used for bird species are given in Appendix 1. The first two CCA axes are displayed. The first axis and second axis account for 42% and 33% of the variance in the carnivorous guild, 51.2% and 33.6% in the herbivorous guild, 38.1% and 30.3% in the omnivorous guild, and 23.4% and 19.2% in the insectivorous guild, respectively

8. ábra Kanonikus korrelációelemzéssel (CCA) készített ordinációk diagramjai az egyes táplálkozási guildok által az élőhelytípusokra adott válaszokról (mw: vegyes fás terület, wg: fás gye, sf: szála (Shorea robusta) erdő, sm: szála-erdő inváziós *Mikania*-val, sc: szála-erdő inváziós *Chromolaena*-val. A madárfajok kódjai az 1. sz. mellékletben szerepelnek. A CCA első két tengelye került feltüntetésre. Az első és a második tengely által magyarázott variancia a ragadozók esetén rendre 42% illetve 33%, a növényevők esetén 51,2% illetve 33,6%, a minde- nevők esetén 38,1% illetve 30,3%, míg a rovarevők esetén 23,4% illetve 19,2%

However, we also detected one globally vulnerable, two near threatened, two nationally vulnerable and four nationally threatened species. We expect that the number of protected species will increase if the surveys are repeated in other seasons because many protected species visit Jalthal Forest seasonally. The main limitation of this study was to collect the data from only one season, which was due to the high impacts of wild elephants in the Jalthal Forest area.

The rank-abundance curve showed that the abundance of high-ranked species declined fast, which hints at low evenness of the community. The relative abundance of lower-ranked species declined gradually, whereas the curve for medium ranked species showed a shallow decline in abundance. This type of RAC is usually common in communities which are at equilibrium state (Izsák & Pavoine 2012, Pandey *et al.* 2020).

Insectivorous birds were the most abundant, followed by omnivorous and carnivorous birds, whilst frugivorous birds were the least common. This result is consistent with the study of Ghimire *et al.* (2021) and can be explained by the high availability of insects in warm tropical-like forests. Furthermore, most of the insectivorous birds prefer the middle canopy but can also explore the top canopy of the forest as well as the ground. The low abundance of frugivorous birds might be due to the unavailability of fruits in fruiting plants during the survey season (winter). In addition, most of Jalthal Forest is dominated by the tree species sal, which does not offer quality fruits to frugivores.

Heterogeneous habitats typically have a higher bird diversity because they offer a variety of plant species which provides food and shelter for a wide range of birds. In line with this, the diversity of birds was higher in wooded grassland than in other habitat types. Higher diversity in grassland has also been reported in Tu *et al.* (2020). In contrast, the results of Pandey *et al.* (2020) showed that diversity was highest in agricultural areas and in settlements.

Disturbances from vehicles, honking, and human activities usually have a negative impact on the diversity and abundance of birds, which is probably why the richness and abundance of birds usually decrease as the distance to the road decreases (Alexander *et al.* 2019, da Silva & Silva 2020, Leveau & Leveau 2020). Our results contradicted this expectation because the diversity and abundance of birds increased with the decreasing distance to the road. Such a result may be due to the association of habitat on the edge of the forest. The forest is bisected by a motorable road and there is farmland between the road and the forest, which provides a heterogeneous habitat and is utilized by many species of birds (Moges *et al.* 2017, Callaghan *et al.* 2019). The other environmental variables did not show significant relationships with the diversity and abundance of birds. Shrub cover usually increases the bird diversity (Calladine *et al.* 2013). But, in this study, overall abundance ($p < 0.05$) and species richness decreased with shrub cover ($p < 0.001$). This unexpected relationship may be due to invasion of *M. micrantha* and *C. odorata*, because these IAPS cover the usable shrub canopy and makes it difficult to explore by birds.

Furthermore, we noted that the abundance and richness of herbivores were positively related to tree canopy cover. Canopy cover is known to provide excellent nesting sites for the herbivorous birds (Asner *et al.* 2009, Holdo & Mack 2014). Herbivorous birds such as parakeets, barbets and doves are the most abundant species of our study area, and these

species usually live in large flocks (parakeets) and prefer habitats with tall trees. Many trees of the Jalthal forest provide fruits and seeds to these birds, which can explain the higher abundance of herbivores in higher tree canopy cover. In contrast, a negative relationship between tree cover and richness of Carnivores suggested that carnivorous birds did not prefer areas with dense trees, but their abundance was positively related to high shrub cover. Carnivorous birds prefer more heterogeneous habitats and open areas to hunt fishes, snails, small mammals, and birds (Robinson 1994). Eagles and kites hover over the shrubs and hunt other birds, snakes, and small mammals, while egrets, cormorants, herons prefer to hunt on ground (Recher & Holmes 1982, Robinson 1994, Tojo 1996, Combs 2021).

Insectivorous birds such as the drongo (*Dicrurus* spp.), shrikes (*Lanius* spp.), Green Bee-eater (*Merops orientalis*), Black-hooded Orioles (*Oriolus xanthornus*) and omnivorous birds like Eurasian Tree Sparrow (*Passer montanus*), Common Myna (*Acridotheres tristis*), Jungle Babbler (*Turdoides striata*), Rufous Treepie (*Dendrocitta vagabunda*), Lesser Whistling Duck (*Dendrocygna javanica*), Red Whiskered Bulbul (*Pycnonotus jocosus*), etc., were abundant in areas near water sources. Such extensive use of habitat by these birds were also reported by Fisher *et al.* (1972) and Lee *et al.* (2017). The habitat around the water sources is usually rich in both terrestrial and aquatic insect diversity and such areas provide fruit trees, and more prey to insectivorous and omnivorous birds.

The shrub canopy has negatively affected the abundance of insectivores. The movement of insectivorous birds is limited by thick shrub cover, so they usually avoid areas with high shrub cover (Burdick 2005, Lloyd & Martin 2005, Flanders *et al.* 2006). The abundance of omnivorous birds was positively affected by the roads. This is probably a result of the heterogeneity of the habitats near the roads because the forest is usually surrounded by agricultural fields separated by a road. This heterogeneous habitat offers omnivore birds more foraging opportunities making them more abundant in such areas. The richness of carnivores, omnivores, and insectivores, however, were negatively affected by roads nearby, as expected. Many birds usually avoid regularly disturbed habitats (Laurance *et al.* 2004, Benítez-López *et al.* 2010). However, a few species such as Green Bee-eater, Black Drongo (*Dicrurus macrocerus*), Long-tailed Shrike (*Lanius schach*), etc., may prefer the road, which thus increases the abundance but not the richness of birds.

Conclusion

This study, from the one of the most unique forests in Nepal, observed high diversity of birds in the edge of forest where habitat is heterogeneous. Jalthal forest has a unique biodiversity as it is different from the forests of western Nepal regarding species distribution of trees. We found that different feeding guilds responded differently to the habitats invaded by IAPS. In areas with dense IAPS cover, both the richness and abundance of birds were low. Sal forest had the maximum diversity of birds. In general, this study provides strong evidence of the negative impact of IAPS on the diversity of the birds. Hence, this study recommends that the IAPS should be controlled in Jalthal Forest to protect the native species and the unique biodiversity of this area.

Acknowledgements

This study is based on MSc dissertation research and was supported by Forest Action Nepal under the Darwin Initiative, a UK-funded project. We thank Yogendra Bikram Poudel, Shankar Bhandari, Bibek Aryal and Ramu Gautam for helping during the data collection. We also thank every member of the Community Forest User Group of Jalthal Forest for their warm welcome and help.

References

- Aleixo, A. 1999. Effects of selective logging on a bird community in the Brazilian Atlantic forest. – *The Condor* 101(3): 537–548. DOI: 10.2307/1370183
- Alexander, J., Smith, D. A. E., Smith, Y. C. E. & Downs, C. T. 2019. Drivers of fine-scale avian functional diversity with changing land use: an assessment of the effects of eco-estate housing development and management. – *Landscape Ecology* 34: 537–549. DOI: 10.1007/s10980-019-00786-y
- Aravind, N., Rao, D., Ganeshaiah, K., Shaanker, R. U. & Poulsen, J. G. 2010. Impact of the invasive plant, *Lantana camara*, on bird assemblages at Malé Mahadeshwara Reserve Forest, South India. – *Tropical Ecology* 51(2S): 325–338.
- Asner, G. P., Levick, S. R., Kennedy-Bowdoin, T., Knapp, D. E., Emerson, R., Jacobson, J., Colgan, M. S. & Martin, R. E. 2009. Large-scale impacts of herbivores on the structural diversity of African savannas. – *Proceedings of the National Academy of Sciences* 106(12): 4947–4952. DOI: 10.1073/pnas.0810637106
- BCN. 2023. Birds in Nepal. – Bird Conservation Nepal, BirdLife International, Kathmandu, Nepal
- Benítez-López, A., Alkemade, R. & Verweij, P. A. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. – *Biological Conservation* 143(6): 1307–1316. DOI: 10.1016/j.biocon.2010.02.009
- Bergner, A., Avcı, M., Eryiğit, H., Jansson, N., Niklasson, M., Westerberg, L. & Milberg, P. 2015. Influences of forest type and habitat structure on bird assemblages of oak (*Quercus* spp.) and pine (*Pinus* spp.) stands in southwestern Turkey. – *Forest Ecology and Management* 336: 137–147. DOI: 10.1016/j.foreco.2014.10.025
- Bhattarai, K. R., Måren, I. E. & Subedi, S. C. 2014. Biodiversity and invasibility: Distribution patterns of invasive plant species in the Himalayas, Nepal. – *Journal of Mountain Science* 11: 688–696. DOI: 10.1007/s11629-013-2821-3
- Budha, P. B. 2015. Current state of knowledge on invasive and alien fauna of Nepal. – *Journal of Institute of Science and Technology* 20(1): 68–81.
- Burnham, K. P. & Anderson, D. R. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. – Springer Science & Business Media
- Burdick, A. 2005. The truth about invasive species. – *Discover* 26(5): 35–39.
- Butchart, S. H., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J. P., Almond, R. E., Baillie, J. E., Bomhard, B., Brown, C. & Bruno, J. 2010. Global biodiversity: indicators of recent declines. – *Science* 328(5982): 1164–1168. DOI: 10.1126/science.1187512
- Calladine, J., Bielinski, A. & Shaw, G. 2013. Effects on bird abundance and species richness of edge restructuring to include shrubs at the interface between conifer plantations and moorland. – *Bird Study* 60(3): 345–356. DOI: 10.1080/00063657.2013.797953
- Callaghan, C. T., Bino, G., Major, R. E., Martin, J. M., Lyons, M. B. & Kingsford, R. T. 2019. Heterogeneous urban green areas are bird diversity hotspots: insights using continental-scale citizen science data. – *Landscape Ecology* 34: 1231–1246. DOI: 10.1007/s10980-019-00851-6
- Combs, B. P. 2021. Great Blue Heron forages for fish by bill-vibrating. – *Western North American Naturalist* 81(2): 280–284. DOI: 10.3398/064.081.0213
- da Silva, B. G. & Silva, W. R. 2020. Impacts of park roads and trails on a community of Atlantic Forest fruit-eating birds. – *Tropical Ecology* 61(3): 371–386. DOI: 10.1007/s42965-020-00097-3
- Davis, M. A., Thompson, K. & Grime, J. P. 2001. Charles S. Elton and the dissociation of invasion ecology from the rest of ecology. – *Diversity Distributions* 7(1–2): 97–102. DOI: 10.1046/j.1472-4642.2001.00099.x

- Day, M. D., Clements, D. R., Gile, C., Senaratne, W. K., Shen, S., Weston, L. A. & Zhang, F. 2016. Biology and impacts of Pacific Islands invasive species. 13. *Mikania micrantha* Kunth (Asteraceae) 1. – Pacific Science 70(3): 257–285. DOI: 10.2984/70.3.1
- DHM. 2019. Data of temperature and rainfall. – Department of Hydrology and Meteorology, Kathmandu. Nepal <https://www.dhm.gov.np/>
- Dinanti, R. V., Winarni, N. L. & Supriatna, J. 2018. Vertical stratification of bird community in Cikepuh Wildlife Reserve, West Java, Indonesia. – Biodiversitas Journal of Biological Diversity 19(1): 134–139. DOI: 10.13057/biodiv/d190120
- ESRI. 2019. ArcGIS Desktop: Release 10.8 Redlands, CA. – Environmental Systems Research Institute
- Fisher, C. D., Lindgren, E. & Dawson, W. R. 1972. Drinking patterns and behavior of Australian desert birds in relation to their ecology and abundance. – The Condor 74(2): 111–136. DOI: 10.2307/1366276
- Flanders, A. A., Kuvlesky, Jr., W. P., Ruthven, III, D. C., Zaiglin, R. E., Bingham, R. L., Fulbright, T. E. & Hernández, F. & Brennan, L. A. 2006. Effects of invasive exotic grasses on south Texas rangeland breeding birds. – The Auk 123(1): 171–182. DOI: 10.1093/auk/123.1.171
- Gan, X., Cai, Y., Choi, C., Ma, Z., Chen, J., Li, B. & Science, S. 2009. Potential impacts of invasive *Spartina alterniflora* on spring bird communities at Chongming Dongtan, a Chinese wetland of international importance. – Estuarine, Coastal and Shelf Science 83(2): 211–218. DOI: 10.1093/auk/123.1.171
- Gautier, L. 1992. Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King & H. Robinson. – Candollea 47(2): 645–662.
- GGN. 2021. Jalthal Forest Management and Conservation Plan. – Green Government Nepal
- Ghimire, A., Rokaya, M. B., Timsina, B., Bilá, K., Shrestha, U. B., Chalise, M. K. & Kindlmann, P. 2021. Diversity of birds recorded at different altitudes in central Nepal Himalayas. – Ecological Indicator 127: 107730. DOI: 10.1016/j.ecolind.2021.107730
- Grimmett, R., Inskipp, C., Inskipp, T. & Baral, H. S. 2016. Birds of Nepal. – Bloomsbury Publishing
- Holdo, R. M. & Mack, M. C. 2014. Functional attributes of savanna soils: contrasting effects of tree canopies and herbivores on bulk density, nutrients and moisture dynamics. – Journal of Ecology 102(5): 1171–1182. DOI: 10.1111/1365-2745.12290
- Holm, L. G., Plucknett, D. L., Pancho, J. V. & Herberger, J. P. 1977. The World's Worst Weeds. Distribution and Biology. – University Press of Hawaii
- Inskipp, C., Baral, H. S., Phuyal, S., Bhatt, T. R., Khatiwada, M., Inskipp, T., Khatiwada, A., Gurung, S., Singh, P. B., Murray, L., Poudyal, L. & Amin, R. 2016. The Status of Nepal's Birds: The National Red List Series. – Zoological Society of London, UK
- Izsák, J. & Pavoine, S. 2012. Links between the species abundance distribution and the shape of the corresponding rank abundance curve. – Ecological Indicators 14(1): 1–6. DOI: 10.1016/j.ecolind.2011.06.030
- Kandel, P., Thapa, I., Chettri, N., Pradhan, R. & Sharma, E. 2018. Birds of the Kangchenjunga Landscape, the Eastern Himalaya: status, threats and implications for conservation. – Avian Research 9: 1–13. DOI: 10.1186/s40657-018-0100-2
- Karr, J. R. & Roth, R. R. 1971. Vegetation structure and avian diversity in several New World areas. – The American Naturalist 105(945): 423–435. DOI: 10.1086/282735
- Keller, G. S. & Avery, J. D. 2014. Avian use of isolated cottonwood, tamarisk, and residential patches of habitat during migration on the high plains of New Mexico. – The Southwestern Naturalist 59(2): 263–271. DOI: 10.1894/F15-MLK-15.1
- Kessler, A. C., Merchant, J. W., Allen, C. R. & Shultz, S. D. 2011. Impacts of invasive plants on Sandhill Crane (*Grus canadensis*) roosting habitat. – Invasive Plant Science 4(4): 369–377. DOI: 10.1614/IPSM-D-11-00036.1
- Laiolo, P. 2002. Effects of habitat structure, floral composition and diversity on a forest bird community in north-western Italy. – Folia Zoologica Praha 51(2): 121–128.
- Laurance, S. G., Stouffer, P. C. & Laurance, W. F. 2004. Effects of road clearings on movement patterns of understory rainforest birds in central Amazonia. – Conservation Biology 18(4): 1099–1109. DOI: 10.1111/j.1523-1739.2004.00268.x
- Lee, A. T., Wright, D. & Barnard, P. 2017. Hot bird drinking patterns: drivers of water visitation in a fynbos bird community. – African Journal of Ecology 55(4): 541–553. DOI: 10.1111/aje.12384
- Leveau, L. M. & Leveau, C. M. 2020. Street design in suburban areas and its impact on bird communities: Considering different diversity facets over the year. – Urban Forestry Urban Greening 48: 126578. DOI: 10.1016/j.ufug.2019.126578

- Lloyd, J. D. & Martin, T. E. 2005. Reproductive success of Chestnut-collared Longspurs in native and exotic grassland. – *The Condor* 107(2): 363–374. DOI: 10.1093/condor/107.2.363
- Lowe, S., Browne, M., Boudjelas, S. & De Poorter, M. 2000. 100 of the world's worst invasive alien species: a selection from the global invasive species database. – Invasive Species Specialist Group Auckland
- Mangachena, J. R. & Geerts, S. 2017. Invasive alien trees reduce bird species richness and abundance of mutualistic frugivores and nectarivores; a bird's eye view on a conflict of interest species in riparian habitats. – *Ecological Research* 32: 667–676. DOI: 10.1007/s11284-017-1481-0
- Moges, E., Masersha, G., Chanie, T., Addisu, A., bv Mesfin, E. & Beyen, C. W. 2017. Species diversity, habitat association and abundance of avifauna and large mammals in Gonde Teklehimanot and Aresema monasteries in North Gondar, Ethiopia. – *Ecology Evolution* 10(4): 185–91. DOI: 10.5897/IJBC2017.1136
- Pandey, N., Khanal, L. & Chalise, M. K. 2020. Correlates of avifaunal diversity along the elevational gradient of Mardi Himal in Annapurna Conservation Area, Central Nepal. – *Avian Research* 11(1): 1–14. DOI: 10.1186/s40657-020-00217-6
- Pearson, D. E. 2009. Invasive plant architecture alters trophic interactions by changing predator abundance and behavior. – *Oecologia* 159(3): 549–558. DOI: 10.1007/s00442-008-1241-5
- Ramaswami, G., Santharam, B. & Quader, S. 2019. Focal plant and neighbourhood fruit crop size effects on fruit removal by frugivores in a semi-arid landscape invaded by *Lantana camara* L. – *Current Science* 116(3): 405.
- Recher, H. F. & Holmes, R. T. 1982. The foraging behaviour of herons and egrets on the Magela Creek flood plain, Northern Territory. – Australian Government Publishing Service Canberra
- Robbins, C. S. 1981. Bird activity levels related to weather. – *Studies in Avian Biology* 6(627): 301–310.
- Robinson, S. K. 1994. Habitat selection and foraging ecology of raptors in Amazonian Peru. – *Biotropica* 1: 443–458.
- Robinson, S. K. & Holmes, R. T. 1984. Effects of plant species and foliage structure on the foraging behavior of forest birds. – *The Auk* 101(4): 672–684. DOI: 10.2307/4086894
- Rocha, R., Virtanen, T. & Cabeza, M. 2015. Bird assemblages in a Malagasy forest-agricultural frontier: effects of habitat structure and forest cover. – *Tropical Conservation Science* 8(3): 681–710. DOI: 10.1177/194008291500800307
- Seymour, C. L. & Dean, W. 2010. The influence of changes in habitat structure on the species composition of bird assemblages in the southern Kalahari. – *Austral Ecology* 35(5): 581–592. DOI: 10.1111/j.1442-9993.2009.02069.x
- Sharma, L. N. 2018. Harnessing synergies between agriculture and forest restoration – Communities work together to restore forests – an example from Nepal. – IUFRO Member Organization ForestAction Nepal
- Sharma, L. N. 2020. Walking through Jalthal forest exploring diversity, importance and degradation. – ForestAction, Nepal. – <https://forestaction.org/>
- Sharma, L. N., Adhikari, B., Bist, M. R. & Shrestha, B. B. 2020. *Mimosa diplotricha* (Fabaceae): a new report of invasive weed from Eastern Tarai of Nepal. – *Journal of Plant Resources* 18(1): 1–5.
- Sharma, L. N., Tamang, S. R., Poudel, Y. B., Subba, A., Timsina, S., Adhikari, B., Shrestha, H., Gautam, A. P., Kandel, D. R. & Watson, M. F. 2021. Biodiversity beyond protected areas: Gaps and opportunities in community forest. – *Journal of Forest Livelihood* 20(1): 45–61.
- Shrestha, B. B. 2016. Invasive alien plant species in Nepal. – In: Jha, P. K., Siwakoti, M. & Rajbhandary, S. (eds.) *Frontiers of Botany*. – Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, pp. 269–284.
- Shrestha, B. B. 2019. Management of invasive alien plants in Nepal: Current practices and future prospects. – In: Garkoti, S., Van Bloem, S., Fulé, P. & Semwal, R. (eds.) *Tropical Ecosystems: Structure, Functions and Challenges in the Face of Global Change*. – Springer, pp. 45–68. DOI: 10.1007/978-981-13-8249-9_4
- Shrestha, B. B. & Shrestha, K. K. 2021. Invasions of Alien Plant Species in Nepal: Patterns and Process. – In: Pullaiah, T. & Ielmini, M. R. (eds.) *Invasive Alien Species: Observations Issues from Around the World 2*, Chap. 8: 168–183. DOI: 10.1002/9781119607045.ch20
- ter Braak, C. J. & Smilauer, P. 2002. CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). – Microcomputer Power (Ithaca, NY, USA). – www.canoco.com. 2002–500
- Tojo, H. 1996. Habitat selection, foraging behaviour and prey of five heron species in Japan. – *Japanese Journal of Ornithology* 45(3): 141–158. DOI: 10.3838/jjo.45.141
- Tu, H. M., Fan, M. W. & Ko, J. C. J. 2020. Different habitat types affect bird richness and evenness. – *Scientific Reports* 10: 1–10. DOI: 10.1038/s41598-020-58202-4

Weber, E. 1960. Invasive plant Species of the World: A Reference Guide to Environmental Weeds. 2nd ed. – Cabi
Weidlich, E. W., Flórido, F. G., Sorrini, T. B. & Brancalion, P. H. 2020. Controlling invasive plant species in
ecological restoration: A global review. – Journal of Applied Ecology 57(9): 1806–1817. DOI: 10.1111/1365-
2664.13656
Wilcox, J. & Beck, C. W. 2007. Effects of *Ligustrum sinense* Lour. (Chinese privet) on abundance and diversity
of songbirds and native plants in a southeastern nature preserve. – Southeastern Naturalist 6(3): 535–550.
DOI: 10.1656/1528-7092(2007)6[535:EOLSLC]2.0.CO;2
Yahner, R. H. 1982. Avian use of vertical strata and plantings in farmstead shelterbelts. – The Journal of Wildlife
Management 1: 50–60. DOI: 10.2307/3808407
Zachariades, C., Day, M., Muniappan, R. & Reddy, G. V. P. 2009. *Chromolaena odorata* (L.) King and Robinson
(Asteraceae). – In: Muniappan, R. Reddy, G. V. P. & Raman, A. (eds.) Biological Control of Tropical Weeds
Arthropods. – Cambridge University Press, Cambridge, Chap. 8: 130–62.
Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, G. M. 2010. Mixed Effects Models and Extensions
in Ecology with R. – Springer Science & Business Media

Appendix 1. Checklist of the birds observed from Jalthal Forest. Here, MS= Migratory status, R= residential, W= winter migratory birds, LC= Least concern, VU= vulnerable, NT= Near threatened, NRDB= National Red Data Book

1. melléklet A Jalthal-erdőben megfigyelt madarak listája. MS: vonulási státusz, R: rezidens, W: téli vendég, LC: nem fenyegetett, VU: sebezhető, NT: mérsékelten fenyegetett, NRDB: nemzeti Vörös Könyv

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
1. Order: Accipitriformes							
Family: Accipitridae							
1	Black Kite	<i>Milvus migrans</i> (Boddaert, 1783)	Omnivorous	SP10	R	LC	LC
2	Crested Serpent-eagle	<i>Spilornis cheela</i> (Latham, 1790)	Carnivorous	SP25	R	LC	LC
2. Order: Anseriformes							
Family: Anatidae							
3	Lesser Whistling-Duck	<i>Dendrocygna javanica</i> (Horsfield, 1821)	Omnivorous	SP54	R	LC	LC
3. Order: Bucerotiformes							
Family: Bucerotidae							
4	Oriental Pied Hornbill	<i>Anthracoceros albirostris</i> (Shaw & Nodder, 1807)	Omnivorous	SP61	R	NT	LC
Family: Upupidae							
5	Common Hoopoe	<i>Upupa epops</i> Linnaeus, 1758	Insectivorous	SP16	R	LC	LC
4. Order: Charadriiformes							
Family: Charadriidae							
6	Red-wattled Lapwing	<i>Vanellus indicus</i> (Boddaert, 1783)	Insectivorous	SP71	R	LC	LC
7	River Lapwing	<i>Vanellus duvaucelii</i> (Lesson, 1826)	Insectivorous	SP73	R	LC	NT
Family: Scolopacidae							
8	Common Sandpiper	<i>Actitis hypoleucos</i> Linnaeus, 1758	Omnivorous	SP21	W	LC	LC

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
5. Order: Ciconiiformes							
Family: Ciconiidae							
9	Black Stork	<i>Ciconia nigra</i> (Linnaeus, 1758)	Carnivorous	SP11	W	VU	LC
10	Lesser Adjutant	<i>Leptoptilos javanicus</i> (Horsfield, 1821)	Carnivorous	SP50	R	VU	NT
11	Asian Woollyneck	<i>Ciconia episcopus</i> (Boddaert, 1783)	Carnivorous	SP86	R	NT	NT
6. Order: Columbiformes							
Family: Columbidae							
12	Eurasian Collared-dove	<i>Streptopelia decaocto</i> (Frisvaldszky, 1838)	Granivorous	SP26	R	LC	LC
13	Oriental Turtle-dove	<i>Streptopelia orientalis</i> (Latham, 1790)	Granivorous	SP62	R	LC	LC
14	Spotted Dove	<i>Spilopelia chinensis</i> (Scopoli, 1786)	Granivorous	SP79	R	LC	LC
15	Red Turtle-dove	<i>Streptopelia tranquebarica</i> (Hermann, 1804)	Granivorous	SP27	R	LC	LC
7. Order: Coraciiformes							
Family: Alcedinidae							
16	Common Kingfisher	<i>Alcedo atthis</i> (Linnaeus, 1758)	Carnivorous	SP18	R	LC	LC
17	White-breasted Kingfisher	<i>Halcyon smyrnensis</i> (Kuhl, 1758)	Carnivorous	SP84	R	LC	LC
Family: Coraciidae							
18	Indian Roller	<i>Coracias benghalensis</i> (Linnaeus, 1758)	Carnivorous	SP44	R	LC	LC
Family: Meropidae							
19	Asian Green Bee-eater	<i>Merops orientalis</i> Latham, 1802	Insectivorous	SP34	R	LC	LC
8. Order: Cuculiformes							
Family: Cuculidae							
20	Common Hawk-cuckoo	<i>Hierococcyx varius</i> (Vahl, 1797)	Insectivorous	SP17	R	LC	LC
21	Greater Coucal	<i>Centropus sinensis</i> (Stephens, 1815)	Omnivorous	SP31	R	LC	LC
22	Lesser Coucal	<i>Centropus bengalensis</i> (Gmelin, 1788)	Omnivorous	SP51	R	LC	LC
9. Order: Galliformes							
Family: Phasianidae							
23	Indian Peafowl	<i>Pavo cristatus</i> Linnaeus, 1758	Omnivorous	SP42	R	NT	LC
10. Order: Passeriformes							
Family: Aegithinidae							
24	Common lora	<i>Aegithina tiphia</i> (Linnaeus, 1758)	Frugivorous	SP19	R	LC	LC

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
Family: Campephagidae							
25	Black-winged Cuckooshrike	<i>Lalage melaschistos</i> (Hodgson, 1836)	Omnivorous	SP8	S	LC	LC
26	Large Cuckooshrike	<i>Coracina javensis</i> (Horsfield, 1821)	Insectivorous	SP48	R	LC	LC
27	Scarlet Minivet	<i>Pericrocotus flammeus</i> (Forster, 1781)	Insectivorous	SP77	R	LC	LC
Family: Cisticolidae							
28	Common Tailorbird	<i>Orthotomus sutorius</i> (Pennant, 1769)	Insectivorous	SP23	R	LC	LC
Family: Corvidae							
29	House Crow	<i>Corvus splendens</i> (Vieillot, 1817)	Omnivorous	SP40	R	LC	LC
30	Eastern Jungle Crow	<i>Corvus macrorhynchos</i> (Wagler, 1827)	Omnivorous	SP68	R	LC	LC
31	Rufous Treepie	<i>Dendrocitta vagabunda</i> (Latham, 1790)	Omnivorous	SP75	R	LC	LC
Family: Dicruridae							
32	Ashy Drongo	<i>Dicrurus leucophaeus</i> Vieillot, 1817	Insectivorous	SP2	W	LC	LC
33	Black Drongo	<i>Dicrurus macrocercus</i> Vieillot, 1817	Insectivorous	SP7	R	LC	LC
34	Greater Racquet-Tailed Drongo	<i>Dicrurus paradiseus</i> (Linnaeus, 1766)	Insectivorous	SP33	R	LC	LC
35	Lesser Racquet-Tailed Drongo	<i>Dicrurus remifer</i> (Temminck, 1823)	Insectivorous	SP53	R	LC	LC
36	Spangled Drongo	<i>Dicrurus bracteatus</i> (Gould, 1842)	Insectivorous	SP78	R	LC	LC
Family: Estrilidae							
37	Scaly-breasted Munia	<i>Lonchura punctulata</i> (Linnaeus, 1758)	Granivorous	SP76	R	LC	LC
Family: Hirundinidae							
38	Barn Swallow	<i>Hirundo rustica</i> Linnaeus, 1758	Insectivorous	SP6	R	LC	LC
Family: Laniidae							
39	Brown Shrike	<i>Lanius cristatus</i> Linnaeus, 1758	Insectivorous	SP13	W	LC	LC
40	Grey-backed Shrike	<i>Lanius tephronotus</i> (Vigors, 1831)	Insectivorous	SP35	W	LC	LC
41	Long-tailed Shrike	<i>Lanius schach</i> Linnaeus, 1758	Insectivorous	SP58	R	LC	LC
Family: Leiothrichidae							
42	Jungle Babbler	<i>Turdoides striata</i> (Dumont, 1823)	Omnivorous	SP49	R	LC	LC
Family: Motacillidae							
43	Olive-backed Pipit	<i>Anthus hodgsoni</i> Richmond, 1907	Omnivorous	SP59	W	LC	LC
44	Paddyfield Pipit	<i>Anthus rufulus</i> Vieillot, 1818	Omnivorous	SP64	R	LC	LC

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
45	White-browed Wagtail	<i>Motacilla maderaspatensis</i> (Gmelin, 1789)	Insectivorous	SP82	R	LC	LC
46	White Wagtail	<i>Motacilla alba</i> Linnaeus, 1758	Insectivorous	SP85	W	LC	LC
Family: Muscicapidae							
47	Asian brown flycatcher	<i>Muscicapa dauurica</i> (Pallas 1811)	Insectivorous	SP3	P	LC	LC
48	Common Stonechat	<i>Saxicola torquatus</i> (Linnaeus, 1766)	Insectivorous	SP22	W	LC	LC
49	Oriental Magpie-robin	<i>Copsychus saularis</i> (Linnaeus, 1758)	Insectivorous	SP60	R	LC	LC
50	Pied Bushchat	<i>Saxicola caprata</i> (Linnaeus, 1766)	Insectivorous	SP65	R	LC	LC
51	Verditer Flycatcher	<i>Eumyia thalassinus</i> Swainson, 1838	Omnivorous	SP81	W	LC	LC
Family: Nectariniidae							
52	Purple Sunbird	<i>Cinnyris asiaticus</i> (Latham, 1790)	Nectarivorous	SP67	R	LC	LC
Family: Oriolidae							
53	Black-hooded Oriole	<i>Oriolus xanthornus</i> (Linnaeus, 1758)	Insectivorous	SP9	R	LC	LC
Family: Paridae							
54	Great Tit	<i>Parus major</i> Linnaeus, 1758	Omnivorous	SP30	R	LC	LC
Family: Passeridae							
55	House Sparrow	<i>Passer domesticus</i> (Linnaeus, 1758)	Omnivorous	SP39	R	LC	LC
56	Eurasian Tree Sparrow	<i>Passer montanus</i> (Linnaeus, 1758)	Omnivorous	SP28	R	LC	LC
Family: Pycnonotidae							
57	Red-vented Bulbul	<i>Pycnonotus cafer</i> (Linnaeus, 1766)	Omnivorous	SP70	R	LC	LC
58	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i> (Linnaeus, 1758)	Omnivorous	SP72	R	LC	LC
Family: Rhipiduridae							
59	White-throated Fantail	<i>Rhipidura albicollis</i> (Vieillot, 1818)	Insectivorous	SP83	R	LC	LC
Family: Stenostiridae							
60	Grey-headed Canary-flycatcher	<i>Culicicapa ceylonensis</i> (Swainson, 1820)	Insectivorous	SP37	W	LC	LC
Family: Sturnidae							
61	Indian Pied Starling	<i>Gracupica contra</i> (Linnaeus, 1758)	Omnivorous	SP4	R	LC	LC
62	Bank Myna	<i>Acridotheres ginginianus</i> (Latham, 1790)	Omnivorous	SP5	R	LC	LC
63	Chestnut-tailed Starling	<i>Sturnia malabarica</i> (Gmelin, 1789)	Insectivorous	SP15	R	LC	LC
64	Common Myna	<i>Acridotheres tristis</i> (Linnaeus, 1766)	Omnivorous	SP20	R	LC	LC

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
65	Jungle Myna	<i>Acridotheres fuscus</i> (Wagler, 1827)	Omnivorous	SP46	R	LC	LC
Family: Zosteropidae							
66	Indian White-eye	<i>Zosterops palpebrosus</i> (Temminck, 1824)	Omnivorous	SP63	R	LC	LC
11. Order: Pelecaniformes							
Family: Ardeidae							
67	Cattle Egret	<i>Bubulcus ibis</i> (Linnaeus, 1758)	Carnivorous	SP14	R	LC	LC
68	Great White Egret	<i>Ardea alba</i> Linnaeus, 1758	Carnivorous	SP43	R	LC	LC
69	Intermediate Egret	<i>Ardea intermedia</i> Wagler, 1829	Carnivorous	SP45	R	LC	LC
70	Little Egret	<i>Egretta garzetta</i> (Linnaeus, 1766)	Carnivorous	SP57	R	LC	LC
Family: Threskiornithidae							
71	Red-naped Ibis	<i>Pseudibis papillosa</i> (Temminck, 1824)	Omnivorous	SP69	R	LC	LC
12. Order: Piciformes							
Family: Megalaimidae							
72	Blue-throated Barbet	<i>Psilopogon asiaticus</i> (Latham, 1790)	Insectivorous	SP12	R	LC	LC
73	Coppersmith Barbet	<i>Psilopogon haemacephalus</i> (Müller, 1776)	Frugivorous	SP24	R	LC	LC
74	Lineated Barbet	<i>Psilopogon lineatus</i> (Vieillot, 1816)	Omnivorous	SP55	R	LC	LC
Family: Picidae							
75	Fulvous-breasted Woodpecker	<i>Dendrocopos macei</i> (Vieillot, 1818)	Omnivorous	SP29	R	LC	LC
76	Greater Flameback	<i>Chrysocolaptes lucidus</i> (Scopoli, 1786)	Insectivorous	SP32	R	LC	LC
77	Grey-capped Pygmy Woodpecker	<i>Picoides canicapillus</i> (Blyth, 1845)	Insectivorous	SP36	R	LC	LC
78	Himalayan Flameback	<i>Dinopium shorii</i> (Vigors, 1832)	Insectivorous	SP38	R	LC	LC
79	Black-rumped Flameback	<i>Dinopium benghalense</i> (Linnaeus, 1758)	Insectivorous	SP52	R	LC	LC
13. Order: Psittaciformes							
Family: Psittaculidae							
80	Alexandrine Parakeet	<i>Psittacula eupatria</i> (Linnaeus, 1766)	Herbivorous	SP1	R	NT	NT
81	Plum-headed Parakeet	<i>Psittacula cyanocephala</i> (Linnaeus, 1766)	Herbivorous	SP66	R	LC	LC
82	Rose-ringed Parakeet	<i>Psittacula krameri</i> (Scopoli, 1769)	Herbivorous	SP74	R	LC	LC
14. Order: Strigiformes							
Family: Strigidae							
83	Spotted Owlet	<i>Athene brama</i> (Temminck, 1821)	Carnivorous	SP80	R	LC	LC

SN	Common name	Scientific name	Feeding guild	Code	MS	NRDB	IUCN
84	Jungle Owlet	<i>Glaucidium radiatum</i> (Tickell, 1833)	Carnivorous	SP47	R	LC	LC
85	Asian Barred Owlet	<i>Glaucidium cuculoides</i> (Vigors, 1831)	Carnivorous	SP41	R	LC	LC
15. Order: Suliformes							
Family: Phalacrocoracidae							
86	Little cormorant	<i>Microcarbo niger</i> (Vieillot, 1817)	Carnivorous	SP56	R	LC	LC

