Effect of landscape heterogeneity on diurnal raptor community richness and diversity in Jammu *Shiwaliks*, Jammu and Kashmir

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Abstract

In this study, we examined the richness and diversity of diurnal raptors along with their foraging guilds across different land uses in a sub-tropical landscape during December 2016 to November 2018. A total of 80 vantage points, 19 line transects and 36 road transects were sampled in 33 sites in six different habitat types in the study area where we recorded 3409 individuals of 29 diurnal raptors in 2 orders and 3 families. Significant variation in bird abundance was observed among different habitat types, farmlands being more specious followed by pure forests, water bodies and forest-farmland interfaces. Among the seasons, summers recorded higher abundance followed by winter, monsoon and post-monsoon. A low diversity value (H′=2.22) however was observed for the whole study area with mean monthly highest recorded during February (H′=2.44) and least during June (H′=1.85). Most of the raptors observed for their food types and foraging were predators (n=22) and rest were carrion feeders (n=22). Fourteen among all observed diurnal raptors were winter visitors and 13 residents with 9 reported globally threatened. A moderately high richness of diurnal raptors substantiate high conservation value of these habitats especially the forest patches and farmlands and thus calls for effective management strategies for the conservation and proliferation of raptors in sub-tropical areas of Jammu region.

Introduction

Raptors are among the most dynamic avian species [1] characterized by unique morphological characteristics including strong talons, hooked beaks adaptation to tearing and/or piercing flesh etc. [2]. Because of their life history traits, relatively low population densities; large home ranges [3-5] and high trophic level, raptors are more sensitive to human disturbances [6-7], environmental contamination [3] and extinction [8] than other bird species. Raptors being the top-order predators, are considered excellent indicators of habitat quality [9] and play a potent role in structuring biological communities [10-11], besides, their population dynamics provide useful information of ecosystem status they inhabit [12-15].

High habitat heterogeneity and prey diversity promotes species richness and abundance among raptor communities [16]. Low population densities, slow turnover rates [8,17-18] and their more susceptibility to anthropogenic threats [6-7] leads to huge population decline [19]. Threats to raptors include habitat alteration [20-25], killings [26-27], poisoning [28-34], electrocution [35-38,], collisions with human made structures and vehicles [17,39-40], road killing [41], human consumption [42-43], climate change [44-49] and many more. Most of the raptors are seriously threatened all over the globe like Europe [50-51], Asia, Middle East and Africa [1,52-53]. The vultures across the Indian sub-continent have witnessed a catastrophic decline in their population following the introduction of diclofenac as a veterinary drug in the 1990s [28]. Despite their charisma and immense ecological significance, there is currently no systematic global synthesis of status, threats, or conservation for all raptors [54]. Raptors being the top predators are key taxa in conservation planning [55], regular monitoring of their population status is essential for proper management of natural ecosystems [56]. It thus becomes extremely essential to understand the status and distribution of raptors in different countries and regions [57].

Diurnal birds of prey are the predominant avian predators for natural ecosystems and are amongst the most susceptible species to the impacts of habitat transformations and perturbations [17]. Asia is home to 127 diurnal raptors (accipitriformes and falconiformes) contributing 40% of the total 317 diurnal raptors found all around the globe [58]. Heterogeneous geography, varied topography and great climatic variability makes northwestern Himalayas biodiversity rich region [59]. At the micro scale, 15 species of raptors were recorded from Baltistan, Pakistan occupied Jammu and Kashmir [60], 25 from south-eastern part of Jammu and Kashmir [61] and 13 species from the plains of Jammu city [62]. At regional level, [63] reported 47 species of raptors in three families, Accipitridae (39 species), Falconidae (7) and Pandionidae (1) from the erstwhile state of Jammu and Kashmir (which includes Jammu, Kashmir and Ladakh division). Forty three among these have been reported from Jammu division only. Despite high raptor diversity and species of conservation interest, the information on distribution and diversity of diurnal raptor communities is scanty and equivocal for the sub-tropical forests in the region. Forming one of the largest groups among the birds in the region [63], the raptors have not attracted the attention of bird ecologists from this part of the region, except for a breeding record by [64]. The current work aims to document diversity, richness, abundance, habitat guild and threat status of raptor communities in the Shiwalik region of UT of Jammu and Kashmir.

Material and Methodology

Study area

Organized surveys were carried out in six different habitats in a subtropical region of Jammu Shiwaliks lying at $32^{0}27'$ and $33^{0}50'$ N and $74^{0}19'$ and $75^{0}20'$ E between 317m to 1010m asl elevation and an area coverage of *c.*5000 Km^2 (Fig 1) during December 2016 to November 2018. The study area comprises of heterogeneous landscapes including southern alluvial plains, fallow lands, agricultural areas, urban built-up areas and the pine clad slopes near the Nandani

Wildlife Sanctuary extending eastwards to Kathua region of Jammu division (Table 1, Fig 1). The vegetation comprises of subtropical scrub, broad-leaved associates interspersed with patches of Chirpine at higher elevations. The climate is generally dry sub-humid type and the whole year is divisible into four distinct seasons *i.e.,* spring (February, March - mid-April), summer (mid-April-June), rainy (July-mid-September), and winter (October-January). The maximum summer temperatures range between 36^{o}C and 42^{o}C while the area receives the average annual precipitation of ~ 1000 mm. The surveys were conducted in 33 sampling sites among six distinct ecosystems intended to cover a range of diverse habitats with varied degree of disturbances. The sampling sites have been categorized as pure forests, forest-farmland interfaces, farmlands, urban built-up, greenbelt parks and urban avenues and water bodies (Table 1).

Data Collection

The selection of sampling sites and sampling intensity was based on 15 days reconnaissance surveys conducted in the possible raptor occupancy sites in Jammu Shiwaliks. Transect method involving road transect of 25-60 km length [65], line transect (2-3 kms) and point count methods were used for counting the birds. For each transect, we recorded the number of species and individuals seen, activities observed and habitat occupied. To avoid the double count, transects were placed at 15 kms and 250 meters apart for road and line transects, respectively. The vantage points were fixed at the elevated areas for counting soaring raptors within circumference of 2-3 kms. A total of 80 vantage points, 19 line transects and 36 road transects were sampled in six different habitat types in the study area (Table 1).

Transects were walked / travelled during morning (2 hrs after sunrise) and evening hours (before dusk). Sampling was avoided during inclement weather conditions like storm, rain or fog. A few opportunistic sightings recorded close to the predefined sampling locations have also been included for the analysis. Field excursions were carried out with the aid of 10x50

binocular and Canon Eos 7D Mark II DSLR with 100*400 mm telephoto lens. Species identification was done by using standard field guide [66-68] and online bird identification platforms like J&K Birdlife, Indian Birds, Ask id's of Indian Birds. For the systematic list of birds, the work of [69] was followed.

Habitat Characterization and Foraging Behaviour

Based on their food composition and foraging behaviour, the raptors have been categorized as predators (hunt the prey, kill and consume) and carrion eaters (feed on dead animal matter) following [70]. Habitat affinities of raptors were also noted for six habitat types during the surveys. The species were classified in different threat categories following IUCN Red List of threatened species [71].

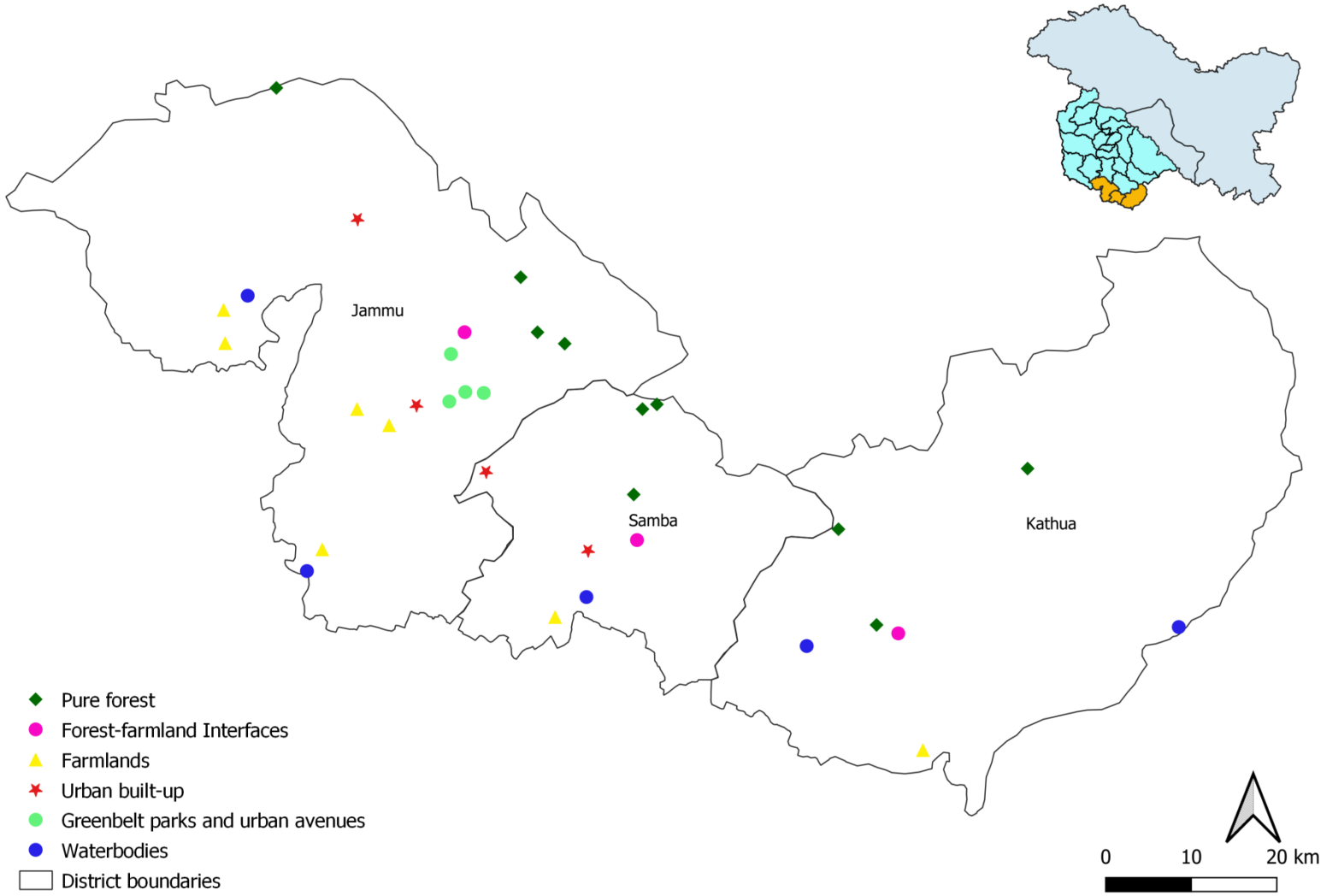

Fig 1: Map showing the location of sampling sites in the study area

147 **Data Analysis**

148 **Richness and diversity attributes**

149 Species diversity was considered the pooled number and summed abundance of each species
150 across all months, seasons, study sites and entire study area. It was calculated using Shannon-
151 Weiner [72] and [73] Simpson's indices while species richness, taken as the number of species
152 per unit area [74] was obtained by [75] and [76] index. Evenness was calculated following
153 [77] and [78]. The statistical analysis was performed in PAST software package ver. 3.06 [79].
154 The Relative abundance (RA) of the birds was calculated by using the following formula;

155 **RA** = No. of individuals of one species / Total no. of individual of all species X 100

156

157 Significant differences in the species abundance among the four seasons *i.e.,* Winter, Summer,
158 Monsoon and Post-monsoon was compared using one-way ANOVA followed by Tukey's
159 multiple comparison tests [80]. Since the data was not normal (Shapiro Wilk $W = 0.46$, $df = 116$, $p < 0.05$), it was transformed to a logarithmic scale (log10) before the analysis. Similarly,
161 Kruskal-Wallis test and Mann-Whitney U-test were applied to species abundance and richness
162 values among the habitat types which appeared non-normal. The statistical tests were
163 performed using SPSS (version 25) software packages with significance tested at $p = 0.05$.

164 **Table 1: Characteristic features of the sampling sites with details on geo-features, transects and the level of disturbance**

Study Site	Transect type/ No	Sampling sites	Geo-Coordinates	Elev. (in m)	Habitat types	Disturbance
Pure forest	Road=13	Kalidhar	33.0500N, 74.6500E	845	Dominated by Chirpine-broadleaved mixed forests	Low
	Line=5	Billawar	32.6480N, 75.5880E	1176	Sub-tropical broadleaved forests dominated with Chirpine at hill tops	Moderate
	Point=42	Galak	32.5850N, 75.3520E	610	Rocky outcrops interspersed with open grassy slopes and Chirpine forests.	Moderate
		Nandini Wildlife Sanctuary	32.8510N, 74.9560E	610	A protected area characterized with sub-tropical deciduous forests interspersed with Chirpine.	Low
		Jasrota Wildlife Sanctuary	32.4840N, 75.3990E	560	Sub-tropical dry deciduous forest interspersed with thick bamboo stands	Low
		Sarain	32.6220N, 75.0970E	475	Sub-tropical dry open scub	High
		Bhed devta	32.7930N, 74.9770E	447	River bed and riparian forest	Moderate
		Badgah (Surinsar)	32.7810N, 75.0110E	632	Lake, agriculture and human habitations	Low
		Buttal (Mansar)	32.7170N, 75.1260E	674	Lake, agriculture and commercial setups	Low
		Kumbi	32.7120N, 75.1080E	772	Plateau with sparse Chiprine stands overlooking deep ravines and gorges	Moderate
Forest-farmland Interfaces	Road=2	Ujh Barrage	32.4750N, 75.4260E	386	A lacustrine ecosystem surrounded with plantations, farmlands and habitations.	Moderate
	Line=1	Nagrota	32.7930N, 74.8860E	430	Undulating valleys with flat sub-tropicalhills	High
	Point=5	Samba	32.5740N, 75.1010E	354	Subtropical dry scrub and vast agriculture landscapes southwards	High
Farmlands	Road=8	Jourian	32.8160N, 74.5850E	268	Vast cultivable farmlands	Low
	Line=4	Pargwal	32.7990N, 75.5950E	263	Waterlogged fields and fallows	Low
	Point=11	Kokerian	32.7120N, 74.7520E	265	A wide and shallow channel of river Tawi	High
		Khakryal	32.3520N, 75.4560E	289	Vast arable agriculture landscapes	Low
		Phallian Mandal	32.6950N, 74.7920E	275	Low lying farmlands and fallow lands	High
		Koulpur	32.4930N, 74.9990E	303	Vast open rice fields	Low
		Gharana cultivation fields	32.5410N, 74.6900E	263	agriculture landscapes dotted with habitations around Gharana wetland conservation reserve	Moderate
Urban built-up	Road=4	Nikki Tawi	32.7160N, 74.8260E	289	A natural off shoot of river Tawi southwards of Jammu City, with moderate pollution load	Very high
	Line=1	Bari Brahmana	32.6460N, 74.9130E	332	Industrial area surrounded by vast wastelands and fallows	High
	Point=4	Udhampur	32.9500N, 75.1560E	800	Subtropical deciduous forests and valleys in middle Shiwaliks	High
		Vijaypur	32.5630N, 75.0400E	340	Sub-urban area along the right bank of seasonal Devak stream	High
Greenbelt parks and urban avenues	Road=3	Raika	32.7290N, 74.9100E	515	A raised forest with a mix of native and introduced trees. Understory comprises of native shrubs	Moderate
	Line=5	Mahamaya	32.7300N, 74.8870E	402	A natural remnant of forest, a designated protected area	Low

	Point=2	Manda	32.7700N, 74.8690E	551	Urban patch bordering Ramnagar Wildlife Sanctuary northwards of Jammu city.	Low
		Jammu University	32.7200N, 74.8670E	317	A green residential campus sprawled in 118 acres on mid of Jammu city along the left banks of river Tawi	Low
Water bodies	Road=6	Daya chak	32.4620N, 75.3120E	362	Vast landmass dotted with water bodies	High
	Line=3	Basantar	32.5140N, 75.0380E	313	A perennial medium stream with sandy bed drains Samba and adjoining villages	Moderate
	Point=16	Jourian	32.8160N, 74.5850E	268	Vast landmass of irrigated agricultural land	Low
		Gharana Wetland	32.5410N, 74.6900E	263	A designated protected wetland and important Bird Area, a heaven for winter migrants.	Moderate
		Purthu (Basohli)	32.4800N, 75.7750E	525	South-western part of vast Ranjit Sagar Reservoir in district Kathua	Low

Results

Species abundance

The study reported a total of 3409 individuals of 29 diurnal raptors in 2 orders and 3 families with 27 species belonging to family Accipitridae and one each to Pandionidae and Falconidae, respectively (Table 3). Most of the species have been observed in the farmlands (26 species) followed by pure forests (25 species), water bodies (22 species) and forest-farmland interfaces (16 species). The less specious habitats included urban built-up (11 species), green belt parks and urban avenues (9 species), each. Urban built-up recorded the highest mean population of 34.68 ± 21.44 raptors followed by pure forests (27.68 ± 9.71), farmlands (18 ± 4.81), forest-farmlands interfaces (13.58 ± 6.24), Green belt parks and urban avenues (11.48 ± 7.69, each) and water bodies (12 ± 3.44). Kruskal-Wallis test revealed a significant variation in bird abundance among the habitat types ($H = 29.60$; $df = 5$; $p < 0.05$) (Fig 2). The highest relative abundance was observed for *Milvus migrans lineatus* (RA=36.53) followed by *Neophron percnopterus* (RA=13.59) and *Aquila nipalensis* (RA=10.83). *Aquila fasciata* and *Aquila rapax* observed only twice during the entire survey period, showed the least relative abundance of 0.06, each (Table 3, Fig 3). When compared season wise, the highest species abundance was recorded during summer (40.93 ± 16.52) followed by winter (32.21 ± 11.19), monsoon (30.28 ± 13.58) and post-monsoon (14.13 ± 5.15). The seasons however did not play any significant role in governing the abundance of the species (ANOVA, $F = 1.20$, $df = 3$, $p = 0.312$) (Fig 4), the habitats exhibited, though. Pure forests showed a significant variation in raptor abundance when compared with forest-farmland interface ($z = -2.10$, $n = 58$, $p = 0.035$), urban built-up ($z = -3.43$, $n = 58$, $p = 0.001$) and green belt parks and urban avenues ($z = -3.63$, $n = 58$, $p = 0.000$); water bodies in relation to urban built-ups ($z = -2.89$, $n = 57$, $p = 0.004$); green belt parks and urban avenues ($z = -3.16$, $n = 57$, $p = 0.002$); farmlands with forest-farmland interfaces ($z = -2.39$, $n = 58$, $p = 0.017$), urban build-

ups (z = -3.62, n = 58, p = 0.000) and green belt parks and urban avenues (z = -3.83, n = 58, p = 0.000). No-significant variation was however observed for the raptor abundance between water bodies and pure forests (z = -0.56, n = 57, p = 0.575), farmlands (z = -1.47, n = 57, p = 0.141) and forest-farmland interfaces (z = -0.74, n = 57, p = 0.456); urban built up with forest-farmland interfaces (z = -1.39, n = 58, p = 0.16) and green belt parks and urban avenues (z = -0.431, n = 58, p = 0.666).

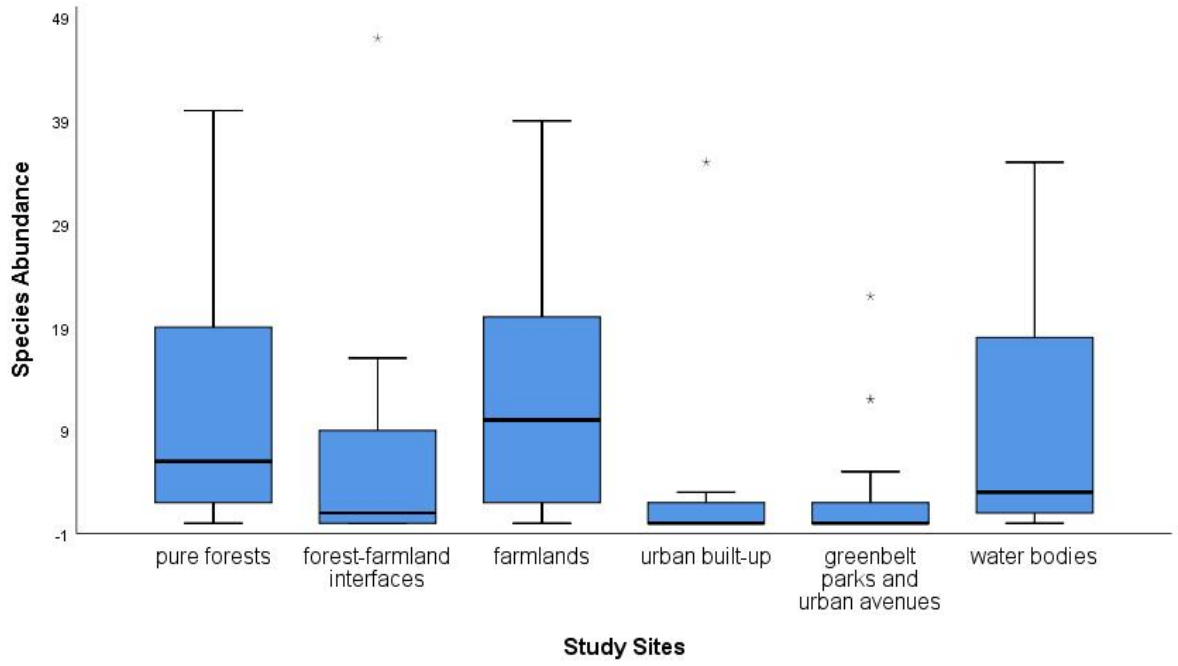

Fig 2. Bird species abundance among different habitats

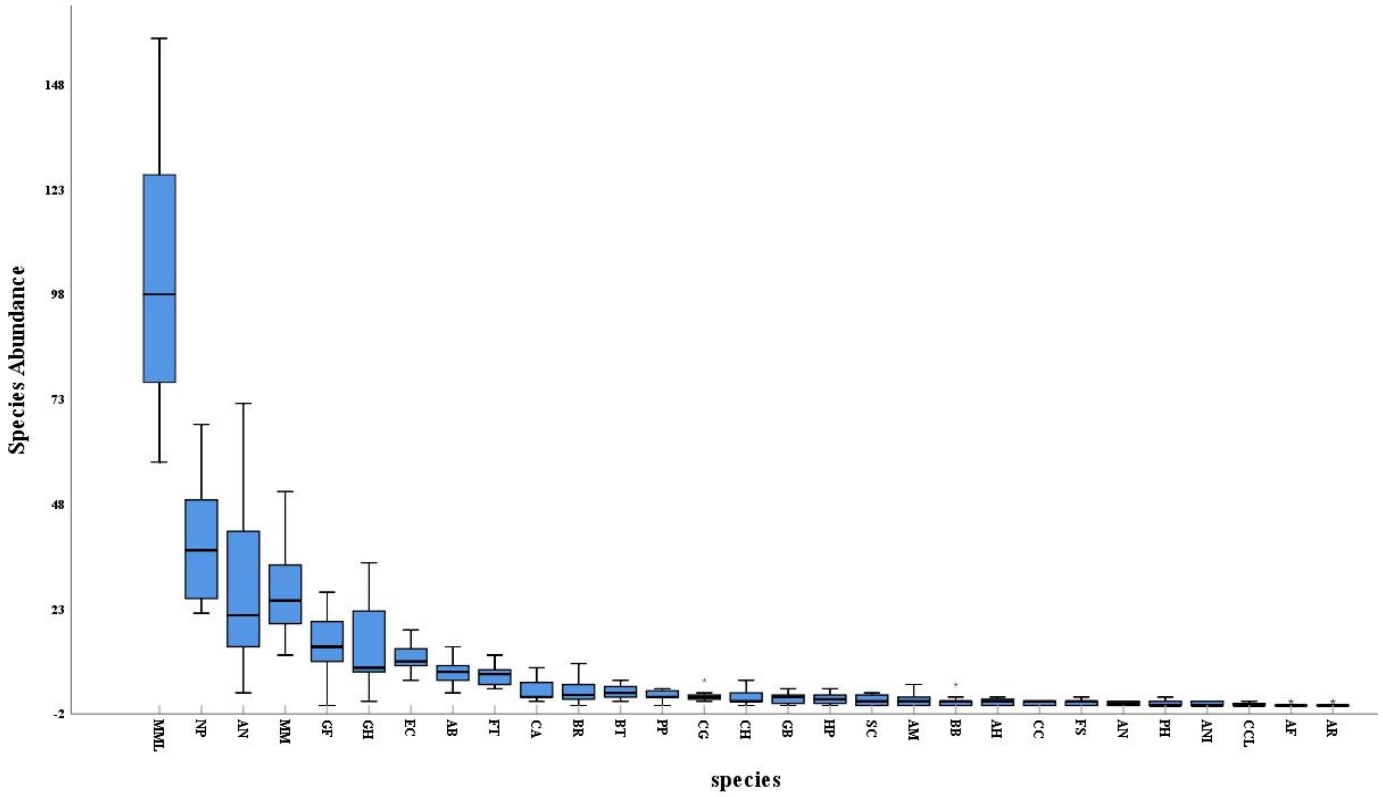

Fig 3: Mean abundance of each species MML: *Milvus migrans lineatus;* NP: *Neophron percnopterus;* AN: *Aquila nipalensis*, MM: *Milvus migrans*, GF: *Gyps fulvus*; GH: *Gyps himalayensis*; EC: *Elanus caeruleus*; AB: *Accipiter badius*; FT: *Falco tinnunculus*; CA: *Circus aeruginosus*; BR: *Buteo rufinus*; BT: *Butastur teesa*; PP: *Pernis ptilorhynchus;* CG: *Circaetus gallicus*; CH: *Clanga hastata*; GB: *Gyps bengalensis*; HP: *Hieraaetus pennatus*; SC: *Spilornis cheela*; AM: *Aegypius monachus*; BB: *Buteo buteo*; AH: *Aquila heliacal*; CC: *Circus cyaneus*; FS: *Falco subbuteo*; AN: *Accipiter nisus*; PH: *Pandion haliaetus*; ANI: *Accipiter nisus*; CCL: *Clanga clanga*; AF: *Aquila fasciata*; AR: *Aquila rapax*

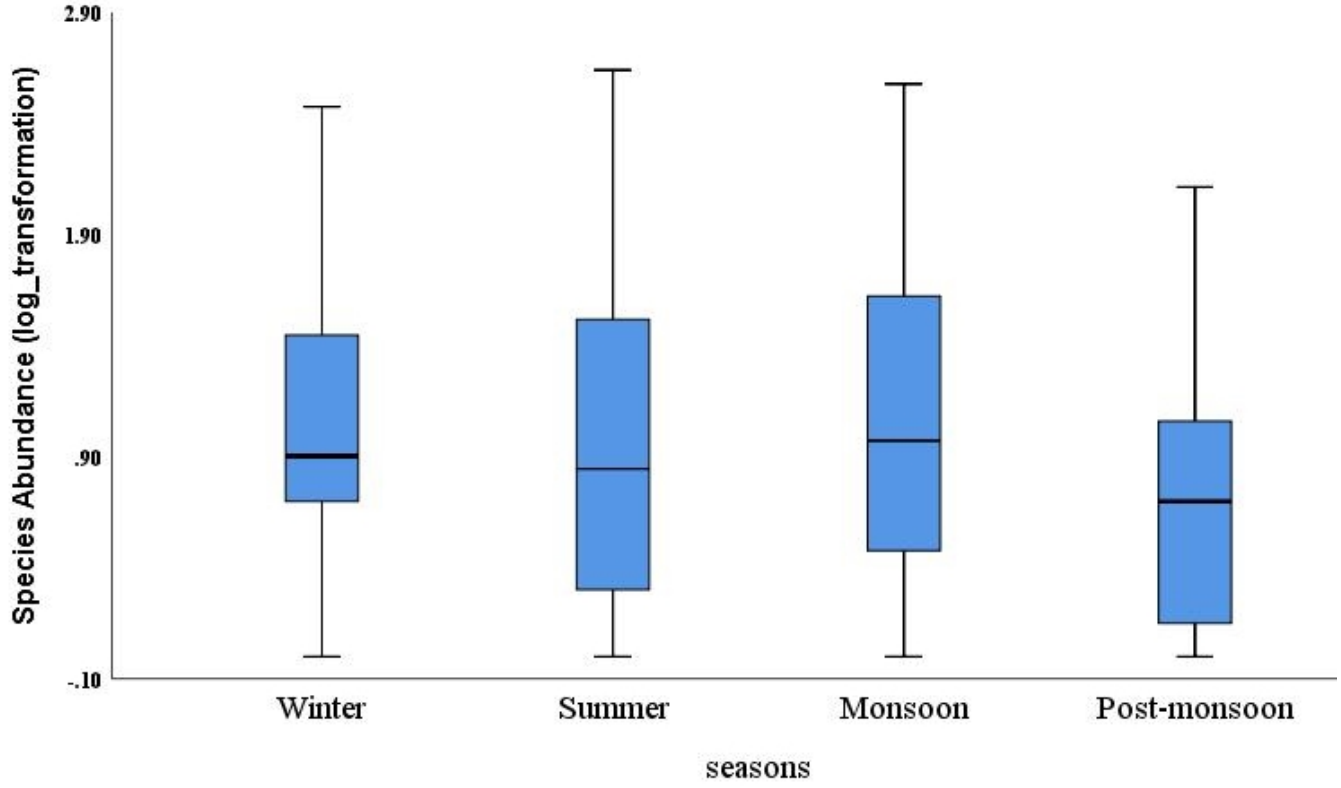

Fig 4: Bird species abundance among seasons

Species richness and diversity

The richness and diversity attributes showed interesting results for different habitats. Maximum value for Menhinick's and Margalef richness indices were recorded during November (D_{Mn}= 1.69), and December (D_{Mg}= 4.60), respectively (Table 2). When compared for the seasons, post-monsoon revealed maximum species richness (D_{Mn}= 1.33; D_{Mg}= 4.32) followed by winters (D_{Mn}= 0.95; D_{Mg}= 4.09), summers (D_{Mn}= 0.78; D_{Mg}= 3.67) while monsoon showed the least (D_{Mn}= 0.74; D_{Mg}= 3.1) (Table 2). Kruskal-Wallis test revealed a significant variation in bird species richness among the different habitats ($H = 21.9$; $df = 5$; $p = 0.001$). Post doc Mann-Whitney U-test showed variations in species richness for pure forests when compared with forest-farmland interfaces, urban build-ups, green belt parks and urban avenues ($P < 0.05$). *Neophron percnopterus, Milvus migrans* and *Accipiter*

244 *badius* found in all the habitat types, were considered generalists. *Pandion haliaetus, Aquila rapax,*
245 *Clanga clanga, Circus cyaneus, Aquila heliacal, Buteo buteo, Spilornis cheela, Circaetus gallicus,*
246 *Butastur teesa, Circus aeruginosus, Neophron percnopterus* were mostly observed around the water
247 bodies, dry riverbeds, sand beds and agricultural fields. The forest specialists included *Aquila*
248 *nipalensis, Milvus migrans, Gyps fulvus, Gyps himalayensis, Falco tinnunculus, Buteo rufinus,*
249 *Butastur teesa, Pernis ptilorhynchus, Gyps bengalensis, Falco subbuteo, Accipiter nisus* and *Aquila*
250 *fasciata. Milvus migrans lineatus, Neophron percnopterus, Milvus migrans, Accipiter badius, Falco*
251 *peregrines* dominated the urban landscapes. *Milvus migrans, Elanus caeruleus, Accipiter badius,*
252 *Pernis ptilorhynchus, Hieraaetus pennatus* have been recorded around Green belt parks and urban
253 avenues. Interestingly, the endangered *Neophron percnopteeus* and *Aquila nipalensis* revealed the
254 high relative abundance in the study area.
255
256 The diurnal raptor communities showed a moderate diversity with the Shannon Weiner and Simpson's
257 diversity index values as 2.22 and 0.8, respectively. Mean monthly highest diversity (H′ = 2.44 and
258 1-D = 0.87), was observed during February (Table 2) and the least during June (H′= 1.85; 1-D = 0.71).
259 Among the seasons, winter recorded the highest diversity (H′ = 2.41 and 1-D = 0.85) and monsoon the
260 least (H′= 2.02; 1-D = 0.77) (Table 2). The species were observed evenly distributed during the winters
261 with highest evenness index (J = 0.77) observed for February (Table 2). Among all, *Milvus migrans*
262 *lineatus* and *Elanus caeruleus* showed the highest diversity (H′ = 2.44, 1-D = 0.90) whereas *Aquila*
263 *fasciata* and *Aquila rapax* were least diverse (H′ = 0.69) each.
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Whittaker curves and Correspondence analysis ordination

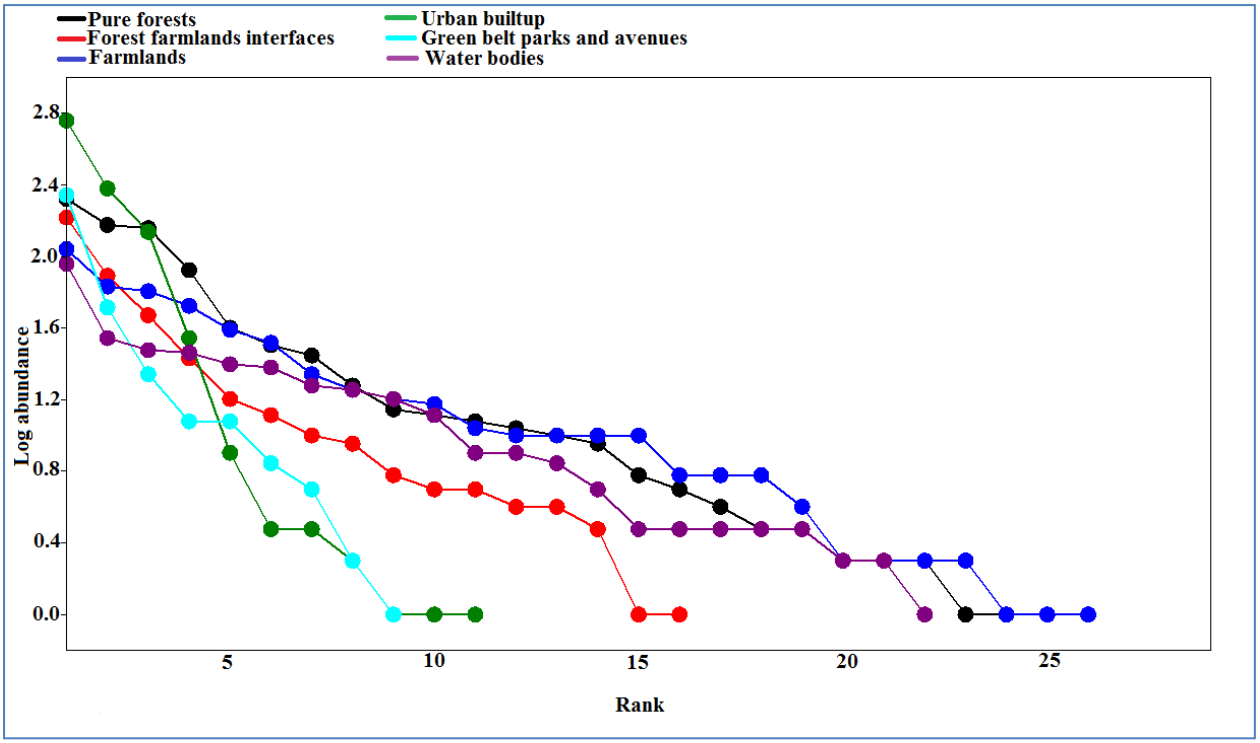
The species diversity among different habitat types is well reflected by Whittaker curves (Fig 5) where urban built-ups and green-belt parks and urban avenues are ranked high with high raptor abundance followed by pure forests and forest-farmland interfaces whereas the farmlands and water bodies ranked low. Pure forests, water bodies, farmlands and forest-farmland interfaces with slanting curves reveal high species richness and evenness whereas the urban built-up and green belt parks and urban avenues behave vice-versa.

Correspondence analysis ordination plot reveals the bird community composition among the habitat types (Fig 6). Most of the species have their distribution restricted to pure forests, water-bodies and farmlands. The pure forests supported the habitats of Crested Serpent eagle (*Spilornis cheela*), Eurasian Hobby (*Falco subbuteo*), Himalayan Vulture (*Gyps himalayensis*), Griffon vulture (*Gyps fulvus*), Eurasian Sparrowhawk (*Accipiter nisus*) and Cinereous vulture (*Aegypius monachus*) whereas farmlands harbored Peregrine Falcon (*Falco peregrines*), Oriental honey Buzzard (*Pernis ptilorhynchus*), Booted Eagle (*Hieraaetus pennatus*), Bonelli's Eagle (*Aquila fasciata*), Steppe eagle (*Aquila nipalensis*), Shikra (*Accipiter badius*), White-rumped vulture (*Gyps bengalensis*), Indian spotted Eagle (*Clanga hastata*), Greater Spotted Eagle (*Aquila rapax*) and Black shouldered Kite (*Elanus caeruleus*). Forest-farmlands and water bodies shared Kites, Eagles, Buzzards and Harriers whereas Kestrels, Osprey, Eastern Imperial Eagle (*Aquila heliacal*), Short-toed Snake Eagle (*Circaetus gallicus*) were found scattered around water bodies. The generalists like Egyptian vulture (*Neophron percnopterus*), Black kite (*Milvus migrans*) and Black-eared kite (*Milvus migrans lineatus*) occupied Urban built up and Green belt parks and avenues.

Table 2: Observed richness and diversity attributes of raptors across months and seasons

Month wise	**Dec**	**Jan**	**Feb**	**W**	**Mar**	**Apr**	**May**	**S**	**Jun**	**Jul**	**Aug**	**Sep**	**M**	**Oct**	**Nov**	**PM**
Taxa (S)	27	25	24	29	25	22	19	27	16	18	16	21	22	21	25	27
Individuals (N)	282	323	329	934	474	392	321	1187	244	231	219	184	878	193	217	410
Diversity Index																
Simpson (1-D)	0.80	0.82	0.87	0.85	0.85	0.78	0.74	0.81	0.71	0.80	0.78	0.75	0.77	0.83	0.82	0.83
Shannon (H′)	2.24	2.28	2.44	2.41	2.25	2.01	1.87	2.11	1.85	2.09	2.01	1.94	2.02	2.23	2.29	2.31
Richness Index																
Menhinick (DMn)	1.60	1.39	1.32	0.95	1.14	1.11	1.06	0.78	1.02	1.18	1.08	1.54	0.74	1.51	1.69	1.33
Margalef (DMg)	4.60	4.15	3.96	4.09	3.89	3.51	3.11	3.67	2.72	3.12	2.78	3.83	3.1	3.8	4.46	4.32
Species Estimate																
Equitability (J)	0.68	0.70	0.77	0.71	0.70	0.65	0.63	0.64	0.67	0.72	0.72	0.63	0.65	0.73	0.71	0.70

Where, **W**–Winter; **S**–Summer; **M**–Monsoons; **PM**–Post-monsoon



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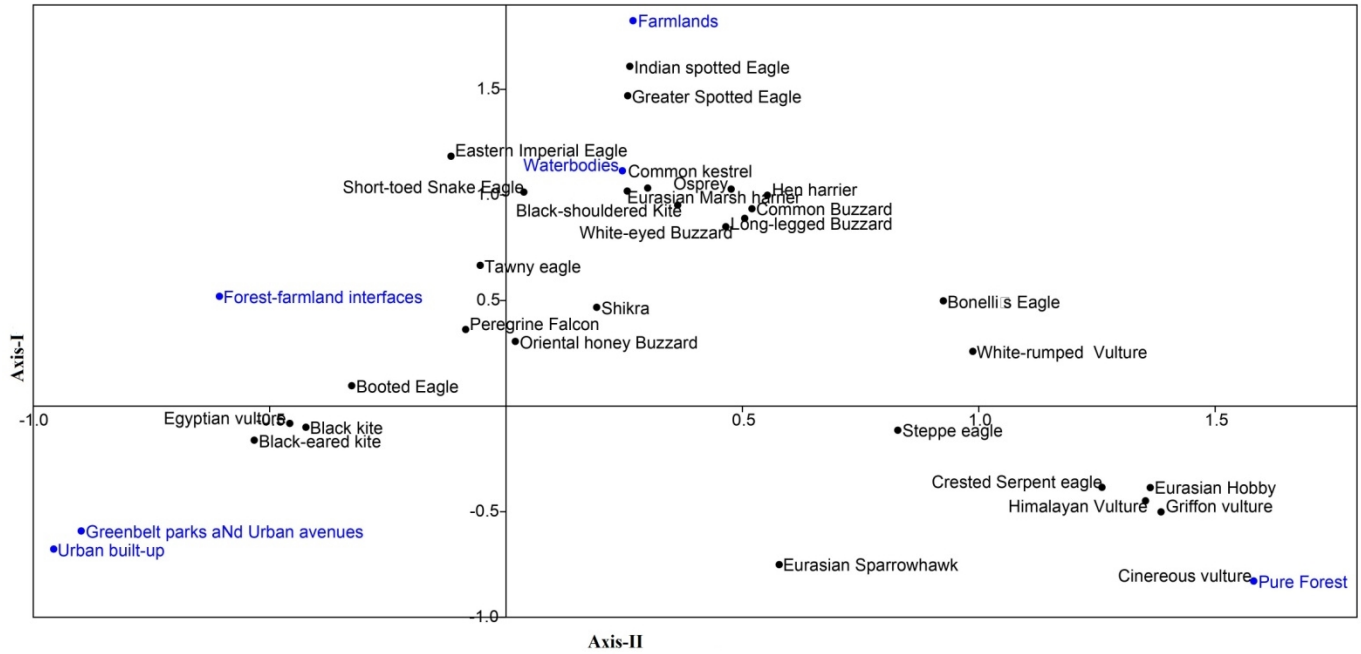
298 Fig 5: Diversity of species among the habitat types.



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301 Fig 6: Correspondence analysis ordination between different habitats
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306 **Feeding, migratory and conservation status**

307 Our observation on food type and feeding behavior revealed that most of the raptors were
308 predators (n= 22) and rest were carrion feeders (n= 7) (Table 3). Fourteen among the total
309 species observed were winter visitors and these included *Aquila nipalensis, Gyps fulvus, Gyps*
310 *himalayensis, Circus aeruginosus, Buteo rufinus, Clanga hastata, Gyps bengalensis, Aegypius*
311 *monachus, Buteo buteo, Aquila heliacal, Circus cyaneus, Clanga clanga, Aquila rapax*and
312 *Pandion haliaetus. Pernis ptilorhynchus* and *Falco subbuteo* were summer visitors whereas
313 the remaining 13 were all residents (Table 3). Nine among the total species so observed were
314 classified as globally threatened (IUCN, 2020). These included *Gyps bengalensis* (critically
315 endangered); *Neophron percnopterus* and *Aquila nipalensis* (endangered), *Clanga hastata,*
316 *Aquila heliacal, Clanga clanga* and *Aquila rapax* (vulnerable); *Gyps himalayensis* and
317 *Aegypius monachus* (near threatened). Twenty species belonged to the least concern category
318 (Table 3).
319

320 **Table 3: List of raptor species recorded in the study area along with their status, guilds and abundance**
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S. No.	Common name	Binomial name	Relative Abundance				RA (%)	MS	Feeding Behaviour	Habitat Guild	IUCN
			Winter (Dec-Feb)	Summer (Mar-May)	Monsoon (Jun-Sep)	Post monsoon (Oct-Nov)					
ORDER: ACCIPITRIFORMES											
Family: Accipitridae											
1	Black-eared kite	*Milvus migrans lineatus*	0.32	0.36	0.43	0.31	36.53	R	Carrion eater	UB,FFI,FL, GPUA,WB	LC
2	Egyptian Vulture	*Neophron percnopterus*	0.10	0.14	0.14	0.15	13.59	R	Carrion eater	UB,FFI,FL, GPUA,WB, PF,	EN
3	Steppe Eagle	*Aquila nipalensis*	0.13	0.13	0.06	0.05	10.83	W	Predator	PF,FL,WB	EN
4	Black Kite	*Milvus migrans*	0.09	0.08	0.08	0.16	9.68	R	Carrion eater	PF,FFI,FL, UB,GPUA, WB	LC
5	Griffon Vulture	*Gyps fulvus*	0.04	0.05	0.05	0.05	5.16	W	Carrion eater	PF,FFI	LC
6	Himalayan Vulture	*Gyps himalayensis*	0.06	0.06	0.03	0.01	5.10	W	Carrion eater	PF,FFI	NT
7	Black-shouldered Kite	*Elanus caeruleus*	0.04	0.02	0.04	0.04	3.99	R	Predator	FFI,FL,WB, GPUA,	LC
8	Shikra	*Accipiter badius*	0.03	0.02	0.02	0.02	2.79	R	Predator	PF,FFI,FL,UB, GPUA,WB	LC
9	Common Kestrel	*Falco tinnunculus*	0.02	0.02	0.03	0.02	2.52	R	Predator	PF,FFI,FL,WB	LC
10	Eurasian Marsh Harrier	*Circus aeruginosus*	0.01	0.013	0.007	0.01	1.29	W	predator	WB,FL,	LC
11	Long-legged Buzzard	*Buteo rufinus*	0.01	0.008	0.009	0.009	1.17	W	Predator	PF,FL,WB, FFI,	LC
12	White-eyed Buzzard	*Butastur teesa*	0.01	0.008	0.013	0.014	1.09	R	Predator	PF,WB	LC
13	Oriental honey-buzzard	*Pernis ptilorhynchus*	0.006	0.006	0.013	0.014	0.88	S	Predator	PF,FFI, GPUA,	LC

14	Short-toed Snake eagle	*Circaetus gallicus*	0.01	0.003	0.008	0.012	0.79	R	Predator	FL,WB,PF,	LC
15	Indian Spotted Eagle	*Clanga hastata*	0.01	0.003	0.002	0.007	0.67	W	Predator	FM,WB	VU
16	White-rumped Vulture	*Gyps bengalensis*	0.005	0.006	0.006	0.007	0.59	W	Carrion eater	WB,PF	CE
17	Booted Eagle	*Hieraaetus pennatus*	0.009	0.005	0.001	0.009	0.56	R	Predator	UB,FFI, GPUA,WB	LC
18	Crested Serpent Eagle	*Spilornis cheela*	0.001	0.005	0.002	0.014	0.44	R	Predator	PF,WB	LC
19	Cinereous vulture	*Aegypius monachus*	0.009	0.002	0	0.009	0.41	W	Carrion eater	PF,	NT
20	Common Buzzard	*Buteo buteo*	0.009	0.002	0.001	0.002	0.35	W	Predator	FL,FFI,WB	LC
21	Eastern Imperial Eagle	*Aquila heliaca*	0.006	0.003	0	0.002	0.29	W	Predator	FL,FFI,WB	VU
22	Hen Harrier	*Circus cyaneus*	0.005	0.002	0	0.004	0.26	W	Predator	WB,FL	LC
23	Eurasian Hobby	*Falco subbuteo*	0.001	0.0008	0.003	0.002	0.18	S	Predator	PF,FL	LC
24	Eurasian Sparrowhawk	*Accipiter nisus*	0.002	0.0008	0.001	0.002	0.15	R	Predator	PF,FL,	LC
25	Tawny Eagle	*Clanga clanga*	0.004	0	0	0	0.12	W	Predator	FL,WB	VU
26	Bonelli's Eagle	*Aquila fasciata*	0.001	0.0008	0	0	0.06	R	Predator	PF,FL	LC
27	Greater Spotted Eagle	*Aquila rapax*	0.001	0	0	0.002	0.06	W	Predator	FL,WB	VU
Family : Pandionidae											
28	Osprey	*Pandion haliaetus*	0.004	0.0008	0	0.002	0.18	W	Predator	FL,WB	LC
ORDER: FALCONIFORMES											
Family: Falconidae											
29	Peregrine Falcon	*Falco peregrinus*	0.005	0.0008	0.003	0.002	0.29	R	Predator	UB,FFI,PF	LC

Discussion

Richness and Abundance

South and southeast Asia is home to high raptor diversity with 219 species recorded so far and of these 102 are found in India [58]. The present study reports 29 species accounting for 42% of the total diurnal raptors in India. This may be attributed to the heterogeneity of landscapes supporting an array of habitats comprising of intact forest patches, protected areas (Jasrota, Nandini, and Surinsar-Mansar Wildlife sanctuaries), rocky ridges, vast fallows and agricultural fields, water bodies (rivers, streams, and ponds), floodplains and urban habitats infused with green belt parks, urban forests and green corridors that provide favorable space for nesting, breeding, perching and roosting and thus high raptor richness and abundance [3,81-84]. Landscape attributes play an important role in determining avian richness and abundance [85-86] which is high in mosaic lands [87-89] limited by suitable breeding habitat and specific nest-site requirements [1,3]. Raptors which have large home ranges encompass a wide range of habitats [90]. Statistical analysis showed a contrasting deviation in species richness among different habitat types. The raptor abundance varied significantly for pure forest, farmlands and water bodies. Variation in bird species abundance could be due to their migratory behavior, food availability, habitat condition, and breeding season of the species [91-92]. Human disturbance is another important factor affecting the abundance and richness of birds [93]. The mean monthly highest values of Menhinick and Margalef richness indices observed for November and December may be attributed to the winter migration. This leads to the overall population inflation and thus the increased diversity as well during the winters.

Presence of raptors in urban areas can be related to stable or abundant prey bases, novel environments, reduced competition, and additional nesting structures [94]. Same holds good with two most abundant raptors observed in the urban environment which included *Milvus*

348 *migrans lineatus* and *Neophron percnopterus*. These generalist species exploit buildings, other
349 human structures and ornamental plantations for shelter, nesting, and food sources (including
350 human-subsidized foods) reaching highest densities in urban areas [95]. Perching sites close to
351 roads (power lines and telephone poles) and road kills increase attractiveness of raptors to urban
352 areas [96]. Urbanization increases biological homogenization and consequently urban adaptable
353 species become increasingly widespread and locally abundant [97]. The green belt parks,
354 avenues, urban forests and green corridors in the present study area act as an ecotonal zone and
355 have been quite successful in providing refuge to the raptor species like *Milvus migrans*
356 *lineatus, Neophron percnopterus, Milvus migrans, Elanus caeruleus, Accipiter badius, Pernis*
357 *ptilorhynchus* and *Hieraaetus pennatus.* Rich plant diversity, availability of perching sites
358 (trees, electricity poles, and telephonic poles) and food resources could be the reason for good
359 species number of raptor in green belt parks and urban avenues.
360
361 Urban avoiders like eagles, hawks, and falcons [98] with specific habitat requirements [95] are
362 more abundant in less-disturbed and natural habitats [95,99-100] that provide safe refugee,
363 hostile environment and the prey species [90]. It comprises the species adapted to live in the
364 interior of forests, migrants, nesting birds sensitive to human presence. The forest dwellers
365 observed during this study included *Accipiter badius*, *Falco subbuteo, Accipiter nisus* and *Falco*
366 *peregrines*, *Gyps fulvus, Gyps himalayensis, Buteo rufinus, Butastur teesa, Pernis*
367 *ptilorhynchus, Circaetus gallicus, Spilornis cheela* and *Aegypius monachus*. Agricultural fields
368 and large open spaces provide breeding and foraging habitats for many open space foragers
369 such as the Eurasian buzzards (*Buteo buteo*), harrier species (*Circus* ssp.), etc [101-104].
370 Besides providing new habitats, irrigated crops provide higher food availability to birds of prey
371 in the form of small mammals, voles and rodents which are ideal foods for western marsh-
372 harrier [105-106], black kites [107-108], black-winged kites and some migrant raptors like

373 booted eagle and steppe eagle [13,109-110]. High raptor abundance in the farmlands and forest
374 farmland interfaces in the study area is attributed to the availability of perching sites (more
375 artificial in the form of poles and high tension / mobile towers) and diverse food options.
376
377 **Feeding, Migratory and Conservation status**
378 Food supply is an important factor governing the raptor density [3] as birds and mammals form
379 the main food for raptors [90] besides reptiles, amphibians, fish and arthropods [111].
380 Pertinently the number of the carrion feeders among the total appeared low but three among
381 seven carrion feeders, *Milvus migrans lineatus, Neophron percnopterus* and *Milvus migrans*
382 were among the top four highly abundant species recorded during the study. Most of them were
383 reported mainly from urban habitats along the road side, near the water bodies and at perches
384 either eating or roosting. Remaining four carrion feeders i.e., *Gyps fulvus, Gyps himalayensis,*
385 *Gyps bengalensis* and *Aegypius monachus* were reported from forests and/or forest farmlands
386 interfaces feeding on cattle that die naturally attracting the large numbers of vultures. Carcass
387 of large animals; deer, hares in forest are the potential source of carrion forming a potent food
388 base for raptors in forests [90,112]. Unlike scavenging raptors, predatory raptors search for their
389 prey visually and hunt those [113]. The observed richness of predatory raptors was quite high
390 than the scavenging ones. This may be attributed to the availability of diverse food availability
391 in mosaic habitats in the study area. [114] reported that food availability is the most important
392 criteria for selecting suitable stopover sites for migratory species and large concentrations of
393 raptors are common in wintering grounds with abundant prey [115] that holds good with the
394 current study. Predatory winter migrants and resident raptors, *Aquila nipalensis, Elanus*
395 *caeruleus, Circus aeruginosus, Buteo rufinus, Butastur teesa, Circaetus gallicus, Clanga*
396 *hastata, Hieraaetus pennatus, Spilornis cheela, Accipiter badius, Buteo buteo Aquila heliacal,*

397 *Clanga clanga, Aquila rapax, Pandion haliaetus* observed in the mosaic habitats, were
398 commonly observed feeding on lizards, rodents, insects, birds, etc.

399 The migratory behaviour of different raptor species in the study area may be due to
400 seasonal movement patterns, local and regional habitat changes, large-scale population changes,
401 and climatic conditions [116-118]. Most of the winter migrants during the study were reported
402 from paddy fields and other farmlands situated close to wetlands or open areas near streams or
403 floodplains and few of them were recorded from forest areas during winters. Migratory species
404 often use paddy fields in winter as foraging sites [119-120]. The forest also serve as alternative
405 habitat for the migratory species which could use the area for resting, foraging till the return of
406 favorable condition [121-122]. The occurrence of 16 migratory species of raptors supports the
407 fact that study area is an important conservation priority area especially for the winter migrants.
408 Out of 26 globally threatened raptor species in India [58] (Bird life international, 2017) nine
409 were observed during the current surveys. *Neophron percnopterus* is resident to the study area
410 and is second most abundant species recorded from the study area whereas *Aquila nipalensis,*
411 *Gyps himalayensis, Clanga hastata, Gyps bengalensis, Aegypius monachus, Aquila heliacal,*
412 *Clanga clanga*and *Aquila rapax* are winter migrant to the region.
413

414 **Conclusions**

415 Our study highlights the importance of urban and suburban areas, forests, streams, floodplains
416 and farmlands for raptor conservation. Combination of natural, semi natural, and urban habitats,
417 are becoming hot spots of landscape diversity that allow a high number of species with
418 contrasting habitat needs. The farmlands and forests harbored the highest species of raptors.
419 Water bodies like streams, rivers and adjoining floodplains too attracted unique raptor species.
420 The conservation value of these mosaic habitat types is not only related to the number of raptor
421 species but also due to inclusion of raptors that need special conservation measures. Indeed,

422 several threatened birds of prey reported from these habitats are rare or even absent in the
423 adjacent protected areas of Jammu Shiwaliks. Holistic actions are needed to implement focusing
424 on ecosystems and habitats essential for maintaining biological diversity, preventing species
425 extinction and increasing the ecological scope for recovery of endangered species. This research
426 work has great implication for combined effort in conservation of raptors in future especially
427 from Himalayan region.
428
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436
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