SEASONAL VARIATION IN BIRD DIVERSITY AND ABUNDANCE IN DARJEELING HILLS OF THE EASTERN HIMALAYA, INDIA

BARKHA RAI*, SHUVAM SHARMA

The Darjeeling part of the Eastern Himalaya is recognized as an important bird and biodiversity area and endemic bird area. The region harbours over 43% of the 986 bird species found in the Himalaya hotspots, many of which are globally threatened and endemic. The birds provide various ecosystem services and these are key indicators of ecosystem health. However, in recent years, these birds are facing significant threats from anthropogenic activities and climate change. This study focuses on documenting of bird diversity in Gangamaya Park, along the IBA corridors in the Darjeeling Hills, India, and examines seasonal variation in the bird community across different habitats through point count method. The study area harboured 93 species, with high species richness observed during the dry season. Passerines comprised 80.6% of the bird species, 58.09% were found in forest habitats, and 61.29% were insectivores. Although, all the species found were under the LC category, 10.75% are listed in CITES appendices, 15% are listed in Convention on Migratory Species Appendix II, and as much as 20% were full migratory. Across season and habitat, Shannon–Weiner index and Simpson's index were consistently higher in the dry season. However, the rainy season showed better species evenness and dominance. Significantly higher species abundance was observed in habitats along the streams in the dry seasons. These findings highlight rich bird species diversity with distinct seasonal variations in the Darjeeling Hills. Despite having high species richness, researches on bird community outside protected areas is very limited. This study will serve as baseline information on seasonal variation in bird species and further the cause for conservation efforts.

Keywords: bird species, rich bird species diversity, distinct seasonal variation, Eastern Himalaya.

INTRODUCTION

The Himalayan region, geographically spanning over 741,706 km^2 from Pakistan to Southeast China (Mittermeier *et al.*, 2004), is one of the most biodiverse landscapes and is recognized as one of the 36 biodiversity hotspots (Myer, 2000; Mittermeier *et al*., 2004; Brooks *et al*., 2006; CEPF, 2016) and "crisis of eco-regions" (Hoekstra *et al*., 2005; Chettri *et al.*, 2010). The region exhibits extreme variation in vegetation, geographic features, and diverse landforms (Arya

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& Gopi, 2021; Rana *et al.*, 2021; Rai, 2023), including most of the world's 14 highest mountain peaks. The gentle rolling plains in the south and snow-capped mountains in the north lies the intersection of two biogeographic realms – Palaeartic and Indo-Malayan (Mohan, 2021). Some of the Asia's largest rivers originate from the Himalayas, sustaining millions of people and numerous lifeforms, including birds. It harbours more than 10,000 flowering plants which 1.1% are endemics, 300 species of mammals (Mittermeier *et al*., 2004), and as many as 987 bird species (Acharya *et al.*, 2024), 39 of which are endemic to this region (Mandal *et al.*, 2018).

Eastern Himalayan region is noted for its avifauna diversity (Kandel *et al.*, 2018; Bhutia *et al*., 2020; Acharya *et al*., 2024). The Darjeeling Hills, forming geographical continuum with the Sikkim Himalaya, are an integral part of the Eastern Himalaya. Covering an area of 2228.13 km^2 (Rai *et al*., 2017), these hills are home to 428 bird species (Biodiversity India, 2012), with the majority concentrated in the three protected areas recognised as Important Bird and Biodiversity Areas (IBAs), and Endemic Bird Areas (EBAs), by Birdlife International.

This mountainous landscape is characterized by a mosaic of tea plantations, 16 distinct forest types, and rich agro-systems (Rai, 2023). With an elevation ranging from 135 m to 3360 m above sea level, the hills encompass tropical to sub-alpine eco-zones. Numerous rivers and rivulets originate and pass through deep valleys. Due to its geographical relief, the hills receive high rainfall brought by the south–west monsoon from June to September, creating distinct dry and rainy season.

These features have significantly contributed to the richness of flora and fauna including the bird species (Ahmad & Yahya, 2010; Kandel *et al*., 2018; Rai, 2023). However, very few studies have been conducted from this region, particularly outside the protected areas (Ahmad & Yahya, 2010; Chettri *et al*., 2018; Samanta *et al*., 2024).

Birds are vital for the functioning of ecosystem, providing a host of ecosystem services including seed dispersal, nutrient cycling, pest elimination, pollination, scavenging, and cultural services (Gaston, 2022). Consequently, they are important indicators of ecosystem health (Whelan *et al*., 2015) and are used for monitoring environmental changes (Fraixedas *et al*., 2020; Shiferaw & Yazezew, 2021). The Himalayan region supports rich avifauna diversity (Kandel *et al*., 2018; Mandal *et al*., 2018; Dendup *et al*., 2021; Dutta *et al*., 2022; Acharya *et al*., 2024). In montane ecosystem, species richness and abundance are markedly influenced by seasonal changes and elevation (Acharya *et al*., 2011; Arya & Gopi, 2021), driven by variables such as temperature, rainfall, habitat, productivity (Kattan & Franco, 2004). Seasonal migration is common in the mountain region (Katuwal *et al*., 2016; Arya & Gopi, 2021).

During winters, many birds migrate to lower elevation to avoid cold weather and food scarcity, while in summer, they expand their range to upper elevation in search of food and suitable breeding habitat (Thomas & Lennon, 1999; Chen *et al*., 2011). Additionally, they act as flyways for long distance migratory birds. Such

movement across altitudinal gradient results in fluctuations in species richness (Stevens, 1992; Katuwal *et al*., 2016; Lee & Kang, 2019).

Birds are facing severe threats. According to the 2023 updated Clement's Checklist by Cornell's Lab of Ornithology, 12% of the 10,906 recorded species are globally threatened (IUCN, 2024). The main causes of the threat are habitat loss, increasing levels of pollution (Bhowmick, 2021; Barton *et al*., 2023), and climate change (Sekercioglu, 2012; Trautmann, 2018). Migratory and aquatic birds, as well as restricted-range species, are particularly vulnerable (Zurell *et al*., 2018). Diversity surrogates are widely used for studying bird globally (Chettri *et al*., 2018; Neupane *et al*., 2020; Arya & Gopi, 2021; Asmare *et al*., 2023).

Diversity indices, which assesses species richness, evenness, abundance, dominance, provides valuable insight into the structure and composition of bird communities (Simpson, 1949; Shannon & Weaver, 1963; Maguran 1988). Statistical tools are increasingly used to compare species richness and abundance (Katuwal *et al*., 2016; Elsen & Ramesh, 2018; Lee and Kang, 2019).

Additionally, information on the feeding guild is essential in understanding habitat requirement and the ecological roles of birds, as well as the capacity of ecosystem to sustains various life forms (Sohil & Sharma, 2020). For example, insectivores contribute to control of insect pests in agro-ecosystems; frugivores assist in the seed dispersal, contributing to plant diversity, carnivores and scavengers help in controlling rodent population and aid in nutrients cycling (Gaston, 2022). The use of these surrogates and comparative studies are crucial for setting conservation priorities (Birdlife International).

The Hills of Darjeeling are known for their rich avifauna diversity, species list for the protected areas are available in various database (ebird, avibase). Few studies outside protected areas, especially documentation of bird species in tea plantation (Ahmad & Yahya, 2010; Chettri *et al*., 2018), have been carried out. Despite the richness of avifauna of the region, studies on bird communities outside the protected areas is negligible.

Therefore, this study aims to document the bird diversity, analyse and compare seasonal patterns of species richness and abundance in the IBAs corridors, between Singalila National Park and Mahananda Wildlife Sanctuary. Baseline information on spatio-temporal distribution of bird species, along with various ecological parameters, will contribute to global conservation efforts.

MATERIAL AND METHODS

Study area

The quaint and serene valley of Gangamaya Park, situated 10 km south of Darjeeling town, is one of the popular tourist destinations. It lies in the corridor between two IBAs – Singalila National Park on the north–west, connecting through the Senchal Wildlife Sanctuary with Mahananda Wildlife Sanctuary on the

south–east direction. It is geographically located between 27º01′57″N latitude and 88º13′33″E longitude, at 1300–1400 m above sea level on the northern fringe of Ghoom Pahar reserve forest. It is characterized by varied land-use pattern, surrounded by tea garden, farmlands, and reserve forest (Fig. 1). The Park is situated at the confluence of two rivulets that flow northward, eventually merging with river Teesta. Ecologically, it represents an ecotone, seamlessly blending sub-tropical and temperate elements. The verdant forests, sprawling tea plantations, and agricultural landscape support the growth and proliferation of diverse flora and the fauna in this unique habitat. The general forest is sub-tropical, with tree species like *Schima wallichii*, *Englehardtia spicata*, *Albizzia lebbeck*, *Alnus nepalensis* forming major components of the forest. Temperate species like *Rhus succedanea*, *Euraya* spp. are of regular occurrence. The proximity of the park to human habitation with farmland, tea gardens, and the forest area and the stream flowing through, supports diverse bird species, making it an ideal habitat for the study of avifauna.

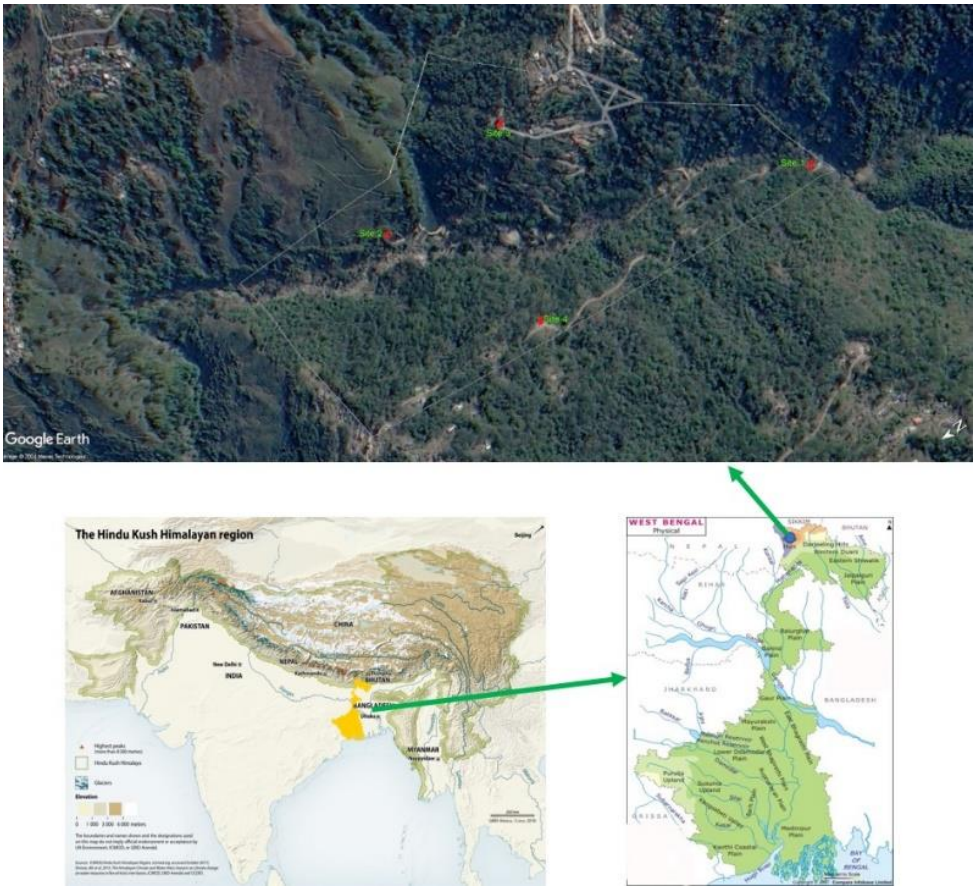

Figure 1. Map showing the sampling sites in Gangamaya Park – Darjeeling Hills of Eastern Himalaya (Source: Google Earth).

Sampling method

Four sampling sites were selected based on different landcover features (Table 1). Sampling was conducted in two seasons, each spanning at least four months. For the dry season, sampling was conducted in March – May and October – November, while the rainy season, it was conducted from June to September to observe differences in species occurrence between seasons. To document the avifauna, point count method was adopted, an effective census technique for estimating diversity (Gibbon & Gregory, 2006; Acharya *et al*., 2011). Four sites around the park area were chosen in different land-use settings, ensuring that the two sites were at least 500 m apart to avoid repetitive counting of the same individual multiple times. Observations were made fortnightly in the morning from 6:00 am to 8:00 am and in the evening from 3:00–5:00 pm, considering the most active times of birds.

Table 1

General information of the study sites in Gangamaya Park

	Site 1	**Site 2**	**Site 3**	**Site 4**
Geographical location	27° 01' 37.69" N Lat. 88° 13' 24.19" E Long.	27°01'58.31" N Lat. 88°13'34.69" E Long.	27° 01' 49.93" N Lat. 88 13 36.29" E Long.	27° 01' 53.40" N Lat. 88° 13' 25.19" E Long.
Altitude	1391 m	1291 m	1398 m	1380 m
Land use	Forest with stream	Tea garden with open woodland and stream	Forest near habitation	Sub-tropical forest

Site 1 – *Riparian forest*; Site 2 – *Tea-garden*; Site 3 – *Open woodland*; Site 4 – *Sub-tropical forest.*

Bird counting was done with a slight modification of Bibby *et al.* (2000). Observers recorded birds seen and heard within a fixed radius of 50 m for 10 minutes from a fixed position at an interval of 30 min. Birds were observed using Nikon ACULON A211 binocular and photographs of the birds were taken by Nikon Coolpix P900 and Nikon Z50 (200–500 mm). Initial identification was done with the help of bird guides (Grimmett *et al*., 2000). Authentication of nomenclature of bird species were done with the help of bird guides (Grimmett *et al*., 2016) and Avibase – The world Bird Database.

Statistical analysis

Initial analysis of the sampled birds was done in MS excel. Diversity indices (Shanon–Weiner index, Simpson Index, Dominance, and Evenness) were computed using in PAlentological STatistical (PAST) 4.13 software (Hammer, 2023). For statistical analysis, the recorded data were subjected to an independent sample

t-test for comparing the mean of species composition and abundance in two seasons across different sites.

RESULTS

Taxonomic diversity

A total of 3166 individuals from 93 species, spanning 69 genera and 37 families across 7 orders were recorded from four sites of Gangamaya Park (Table 2). The order Passeriformes was the most abundant containing 75 species (80.6%), followed by Piciformes with 6 species (6.4%), Accipitriformes, Cuculiformes, and Stigiformes with 3 species each, Galliformes with 2 species, and Columbiformes with a single species. Among the families, Muscicapidae was the largest containing the highest number – 13 species (13.9%) followed by Phyllocopidae with 7 species (7.5%) and Leiothrichidae with 6 species (6.4%), while Nectariniidae, Pycnonotidae, and Zosteroidae with 4 species (4.3%) each (Fig. 2). Other families contained lesser species – 4 families with 3 species (3.2%) each, 13 families with 2 species (2.2%) each, and 17 families with a single species. Season wise taxonomic diversity revealed that the dry season had better species richness (Table 3), with 90 species spanning across 35 families and 66 genera. In comparison, the rainy season recorded 71 species across 37 families and 58 genera.

Guild Structure

Guild analysis reveals that 58.06% (54 species) were found in forests, 30.11% (28 species) in the open woodland, 8.6% (eight species) were stream/water specialists, and three species were exclusively found in the human habitation (Fig. 3). Six different types of feeding habit were recognised (Fig. 4), some being specialist and others opportunistic.

Species like *Hirundo rustica*, *Phoenicurus fuliginosus*, etc. were highly specialized in arial feeding, *Dicrurus hottentottus*, *Aethopyga* sp. in nectar feeding. Species such as *Cinclus pallasii*, *Motacilla cinerea*, *Turdus boulboul*, *Enicurus* sp., and *Phoenicurus* sp. were primarily found along streams and have specialized feeding niches foraging on aquatic insects, small fishes, molluscs, earthworms and more.

Many of these species were opportunistic feeder, capable of switching between herbivorous and other available food resources, exhibiting voracious feeding behaviour. Insectivore constituted 61.29% (57 species), followed omnivore 21.51% (20 species), carnivore and nectivore were represented by 5.38% (five species) each, while frugivore and granivore comprised of 3.23% (three species) each, showing specialized feeding preference. Similarly, 50.53% (47 species) were permanent resident, 30.11% (28 species), exhibited altitudinal migration, and 19.35% (18 species) were full migrants (Fig. 5).

Table 2

Inventory data of the avifauna of Gangamaya Park in Darjeeling Hills of Eastern Himalaya, India

Order	Family	Sl No	Species	Common Name	Conserva-tion status	Rainy season					Dry Season				
						RS1	RS2	RS3	RS4	TOT	DS1	DS2	DS3	DS4	TOT
Accipitriformes	Accipitridae	1	*Accipiter virgatus* AM	Besra	RL (II) CMS (II)					0			2		2
		2	*Buteo refectus*	Himalayan Buzzard	RL (II), CMS(II)			1	2	3			4	2	6
		3	*Ictinaetus malaiensis*	Black Eagle	RL (II)	1		2	1	4			2	2	4
Columbiformes	Columbidae	4	*Columba livia*	Rock Pigeon	LC			15		15			12		12
Cuculiformes	Cuculidae	5	*Cuculus canorus* FM	Common Cuckoo	LC					0	5			4	9
		6	*Cuculus poliocephalus* FM	Lesser Cuckoo	LC	5			3	8	2			1	3
		7	*Hierococcyx varius* FM	Common Hawk-Cuckoo	LC	3		5		8	6			3	9
Galliformes	Phasianidae	8	*Arborophila torqueola*	Hill Partridge	LC			20	15	35	30			20	50
		9	*Lophura leucomelanos*	Kalij Pheasant	RL (III)	4	3		3	10	12	8		2	22
Passeriformes	Aegithalidae	10	*Aegithalos concinnus*	Black-throated Tit	LC	12	15	28	8	63		26	23	26	75
	Campephagidae	11	*Lalage melaschistos* FM	Black-winged Cuckooshrike	LC					0	2		4		6
		12	*Pericrocotus speciosus*	Scarlet Minivet	LC	4	6		7	17	8	10	4		22
	Chloropseidae	13	*Chloropsis hardwickii*	Orange-bellied Leafbird	LC	3			2	5	34	3	6	11	54
	Cinclidae	14	*Cinclus pallasii*	Brown Dipper	LC	6	12			18	5	7			12
	Cisticolidae	15	*Orthotomus sutorius*	Common Tailorbird	LC	3	4	14	6	27			5	6	11
		16	*Prinia atrogularis* AM	Black-throated Prinia	LC					0		7		13	20
		17	*Prinia crinigera* AM	Himalayan Prinia	LC					0		9	12	2	23
		18	*Prinia superciliaris* AM	Hill Prinia	LC					0	3		3	9	15
	Corvidae	19	*Cissa chinensis*	Common Green-Magpie	LC	7		2	6	15	2	6	1	3	12
		20	*Dendrocitta formosae*	Grey Treepie	LC	2		6	3	11	5		2	4	11

Table 2 (continued)

Order	Family	Sl No	Species	Common Name	Conserva-tion status	Rainy season					Dry Season				
						RS1	RS2	RS3	RS4	TOT	DS1	DS2	DS3	DS4	TOT
Passeriformes	Dicaeidae	21	*Dicaeum ignipectus*	Fire-breasted Flowerpecker	LC		6		4	10		29	18		47
	Dicruridae	22	*Dicrurus aeneus*	Bronzed Drongo	LC	1	2	2	4	9	6	5	9	1	21
		23	*Dicrurus hottentottus* FM	Hair-crested Drongo	LC	12	7			19		3		13	16
	Estrildidae	24	*Lonchura striata*	White-rumped Munia	LC		12	18		30					0
	Eurylaimidae	25	*Psarisomus dalhousiae*	Long-tailed Broadbill	LC	9		3	2	14	5			2	7
	Hirundinidae	26	*Hirundo rustica* FM	Barn Swallow	LC			6		6					0
	Laniidae	27	*Lanius schach* FM	Long-tailed Shrike	LC					0			3	3	6
		28	*Lanius tephronotus* FM	Grey-backed Shrike	LC		4		5	9	2	17			19
	Leiothrichidae	29	*Alcippe nipalensis*	Nepal Fulvetta	LC					0		6	4	6	16
		30	*Grammatoptila striata*	Striated Laughingthrush	LC	5			7	12	14		13	23	50
		31	*Heterophasia capistrata*	Rufous Sibia	LC	6	5	14	12	37		31		8	39
		32	*Leiothrix argentauris* AM	Silver-eared Mesia	RL (II)		2	3		5		13		17	30
		33	*Leiothrix lutea*	Red-billed Leiothrix	RL (II)	6		24	13	43	45	23	22	34	124
		34	*Trochalopteron lineatum*	Streaked Laughingthrush	LC		17	12		29	19		8	3	30
	Motacillidae	35	*Anthus hodgsoni* FM	Olive-backed Pipit	CMS (II)		3	2		5		11	7		18
		36	*Motacilla cinerea* FM	Grey Wagtail	CMS (II)	2				2	7	9			16
	Muscicapidae	37	*Anthipes monileger* AM	White-gorgeted Flycatcher	LC					0	13			9	22
		38	*Enicurus maculatus*	Spotted Forktail	LC		3			3	6	14			20
		39	*Enicurus schistaceus*	Slaty-backed Forktail	LC	7	18			25	12	10			22
		40	*Enicurus scouleri*	Little Forktail	LC	3				3	6	7			13

Table 2 (continued)

Order	Family	Sl No	Species	Common Name	Conserva-tion status	Rainy season					Dry Season				
						RS1	RS2	RS3	RS4	TOT	DS1	DS2	DS3	DS4	TOT
Passeriformes	Muscicapidae	41	*Eumyias thalassinus* FM	Verditer Flycatcher	CMS (II)					0		16	6		22
		42	*Ficedula albicilla* FM	Taiga Flycatcher	CMS (II)					0				18	18
		43	*Ficedula strophiata* FM	Rufous-gorgeted Flycatcher	CMS (II)					0	19		13		32
		44	*Muscicapa ferruginea* FM	Ferruginous Flycatcher	CMS (II)					0				20	20
		45	*Myophonus caeruleus* AM	Blue Whistling-Thrush	LC	3	4	2		9	12	18	2		32
		46	*Niltava macgrigoriae*	Small Niltava	LC			3		3	2			2	4
		47	*Phoenicurus fuliginosus*	Plumbeous Water-Redstart	LC	3				3	6	3			9
		48	*Phoenicurus leucocephalus* AM	White-capped Redstart	CMS (II)		4			4	2	7			9
		49	*Tarsiger rufilatus* FM	Himalayan Bush-Robin	CMS (II)					0	6		8		14
	Nectariniidae	50	*Aethopyga ignicauda*	Fire-tailed Sunbird	LC			4	2	6	7		3	4	14
		51	*Aethopyga nipalensis*	Green-tailed Sunbird	LC			2	3	5		4		2	6
		52	*Aethopyga saturata*	Black-throated Sunbird	LC		1	5		6		3		8	11
		53	*Aethopyga siparaja*	Crimson Sunbird	LC			1	3	4	1			2	3
	Paridae	54	*Melanochlora sultanea*	Sultan Tit	LC	3	7	2		12					0
		55	*Parus monticolus*	Green-backed Tit	LC	23	12	22	6	63	20	18	26	17	81
	Passeridae	56	*Passer cinnamomeus* AM	Russet Sparrow	LC			10		10			4		4
	Phylloscopidae	57	*Phylloscopus burkii* FM	Green-crowned Warbler	LC					0	17		18	10	45
		58	*Phylloscopus chloronotus* AM	Lemon-rumped Warbler	CMS (II)	8	10	13	22	53		8	9		17
		59	*Phylloscopus maculipennis* AM	Ashy-throated Warbler	CMS (II)	12	7		24	43	4	18		8	30
		60	*Phylloscopus pulcher* AM	Buff-barred Warbler	CMS (II)					0	16		13	15	44
		61	*Phylloscopus reguloides* AM	Blyth's Leaf Warbler	CMS (II)					0		3		2	5

Table 2 (continued)

Order	Family	Sl No	Species	Common Name	Conserva-tion status	Rainy season					Dry Season				
						RS1	RS2	RS3	RS4	TOT	DS1	DS2	DS3	DS4	TOT
Passeriformes		62	*Phylloscopus whistleri* AM	Whistler's Warbler	LC					0	6	8		3	17
		63	*Phylloscopus xanthoschistos*	Grey-hooded Warbler	LC	12		30	9	51		19	17	3	39
	Pnoepygidae	64	*Pnoepyga pusilla* AM	Pygmy Wren-babbler	LC	3				3	3		4	6	13
	Pycnonotidae	65	*Alcurus striatus* AM	Striated Bulbul	LC		28		19	47	22		10	17	49
		66	*Hypsipetes leucocephalus* FM	Black Bulbul	LC					0		46	52		98
		67	*Pycnonotus cafer*	Red-vented Bulbul	LC		24	8	14	46	13	36	22	14	85
		68	*Pycnonotus leucogenys* FM	Himalayan Bulbul	LC		9	12	6	27	5	9	12	6	32
	Rhipiduridae	69	*Rhipidura albicollis* AM	White-throated Fantail	LC		6	10		16		2	8		10
	Scotocercidae	70	*Cettia castaneocoronata* AM	Chestnut-headed Tesia	LC	15		12		27	16			24	40
		71	*Tesia cyaniventer* AM	Grey-bellied Tesia	LC	2				2	12				12
	Sittidae	72	*Sitta himalayensis*	White-tailed Nuthatch	LC	3			9	12	2		5		7
	Stenostiridae	73	*Chelidorhynx hypoxanthus*	Yellow-bellied Fantail	LC			6		6		6	6		12
		74	*Culicicapa ceylonensis*	Grey-headed Canary-Flycatcher	LC	10		9	12	31	9		3	15	27
	Sturnidae	75	*Gracula religiosa*	Common Hill Myna	RL (II)				2	2	40			26	66
	Timaliidae	76	*Cyanoderma ruficeps*	Rufous-capped Babbler	LC		6	4	1	11		4	11	9	24
		77	*Stachyris nigriceps*	Grey-throated Babbler	LC	2		5	12	19	8			4	12
	Turdidae	78	*Turdus boulboul* AM	Grey-winged Blackbird	LC	4	2			6	5	4			9
	Vireonidae	79	*Pteruthius aeralatus* AM	White-browed Shrike-Babbler	LC		2	3		5		12	9		21
		80	*Pteruthius melanotis*	Black-eared Shrike-Babbler	LC	6			8	14				23	23
	Zosteropidae	81	*Yuhina flavicollis* AM	Whiskered Yuhina	LC					0	14	9		16	39

Table 2 (continued)

Order	Family	Sl No	Species	Common Name	Conserva-tion status	Rainy season					Dry Season				
						RS1	RS2	RS3	RS4	TOT	DS1	DS2	DS3	DS4	TOT
Passeriformes	Zosteropidae	82	*Yuhina gularis* AM	Stripe-throated Yuhina	LC					0			6	7	13
		83	*Yuhina occipitalis* AM	Rufous-vented Yuhina	LC					0		8	10		18
		84	*Zosterops palpebrosus*	Indian White-eye	LC		4	3		7		4		2	6
Piciformes	Megalaimidae	85	*Psilopogon asiaticus*	Blue-throated Barbet	LC	7	2			9	4	6			10
		86	*Psilopogon virens* AM	Great Barbet	LC	2	8		2	12	5	2		3	10
	Picidae	87	*Blythipicus pyrrhotis*	Bay Woodpecker	LC	5			2	7	4		3	3	10
		88	*Dryobates cathpharius*	Crimson-breasted Woodpecker	LC	3			6	9	7		3		10
		89	*Picumnus innominatus*	Speckled Piculet	LC	1			2	3	1			1	2
		90	*Sasia ochracea*	White-browed Piculet	LC	6			1	7			2		2
Strigiformes	Strigidae	91	*Glaucidium cuculoides AM*	Asian Barred Owlet	RL (II)			2	8	10			1	4	5
		92	*Otus spilocephalus* AM	Mountain Scops-Owl	RL (II)			3		3			5	7	12
		93	*Taenioptynx brodiei* AM	Collared Owlet	RL (III)			3		3				3	3
Total						**234**	**255**	**351**	**276**	**1116**	**537**	**527**	**455**	**531**	**2050**

Table 3
Taxonomic diversity of avifauna across two seasons in Gangamaya Park

Order	Rainy Season			Dry Season		
	Families	Genera	Species	Families	Genera	Species
Accipitriformes	1	2	2	1	3	3
Columbiformes	1	1	1	1	1	1
Cuculiformes	1	2	2	1	2	3
Galliformes	1	2	2	1	2	2
Passeriformes	30	43	55	28	50	72
Piciformes	2	5	6	2	5	6
Strigiformes	1	3	3	1	3	3
Total	**37**	**58**	**71**	**35**	**66**	**90**

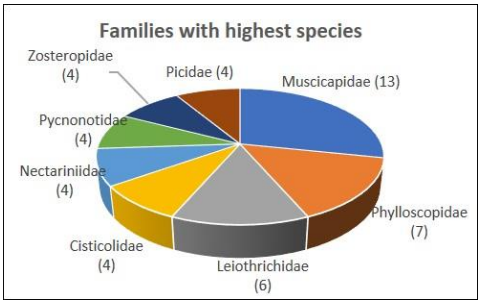

Figure 2. Families contributing highest number of species.

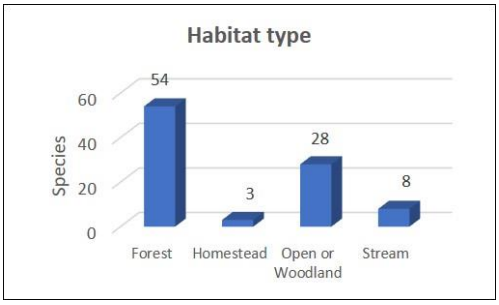

Figure 3. Habitat type of bird species in Gangamaya Park.

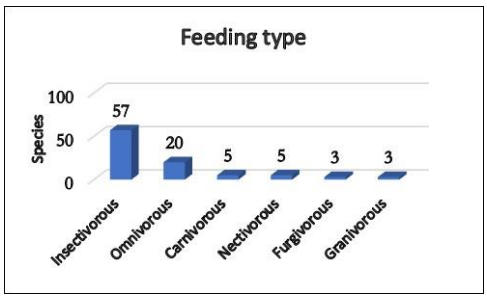

Figure 4. Feeding type of bird species in Gangamaya Park.

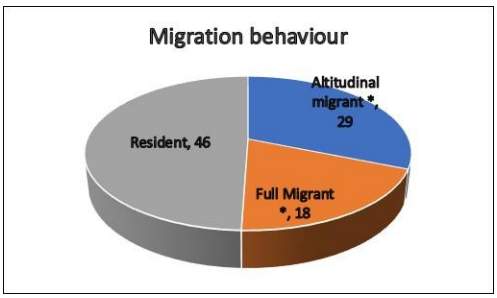

Figure 5. Migratory behaviour of the bird species in Gangamaya Park.

Conservation status

While none of the avifauna recorded were showing global threat, all of them were Least Concerned (LC), however, 10 species (10.75%) are listed in Appendix II and one in Appendix III of the Convention of International Trade on Endangered Species (CITES) (Table 2). These species are represented by *Accipiter virgatus*, *Buteo refectus*, *Ictinaetus malaiensis*, *Leiothrix argentauris*, *Leiothrix lutea*, *Gracula*

religiosa, *Glaucidium cuculoides*, *Otus spilocephalus*, and *Taenioptynx brodiei*. While *Lophura leucomelanos* is listed in Appendix III. Additionally, 14 species (15%) are listed in the Appendix II of the Convention on Migratory Species (CMS). These species are represented by *Accipiter virgatus*, *Buteo refectus*, *Eumyias thalassinus, Ficedula albicilla, Ficedula strophiata, Ictinaetus malaiensis, Motacilla cinerea, Muscicapa ferruginea, Phoenicurus leucocephalus, Phylloscopus chloronotus, Phylloscopus maculipennis, Phylloscopus pulcher*, and *Phylloscopus reguloides.*

Seasonal species richness and abundance

Species richness and bird population were compared across four sites during two seasons. A detail comparison of species richness and abundance is provided in Table 4. During the dry season, we identified 90 species from 66 genera and 35 families, with a total of 2050 individuals.

The highest species richness was found in sub-tropical forest (Site 4) with 59 species and 531 individuals, followed by riparian forest (Site 1) with 53 species and 537 individuals. Open woodland (Site 3) recorded 50 species with 455 individuals, while tea garden (Site 2) had the least number of species (46) with 527 individuals.

In contrast, during rainy season, we recorded 71 species from 58 genera and 37 families, totalling 1116 individuals. Site 3 had the highest number of species (42) with 351 individuals, followed by Site 1 with 41 species and 234 individuals. Site 4 recorded 40 species with 274 individuals, while Site 2 had the least number of species (33) with 255 individuals.

The comparative analysis of seasonal patterns in species distribution and abundance is provided in Fig. 6 (a–f). We found that insectivorous species comprised the highest number in terms of species composition and abundance across sites and seasons. The dry season clearly showed better richness compared to the rainy seasons. Omnivorous species also constituted a significant number of species and abundance, while granivorous comprised of small number such as *Columba livia*, *Passer cinnamomeus*, and *Lonchura striata* were recorded only from site 3, likely due to proximity to human habitation.

Our comparative analysis revealed that altitudinal migrants constitute a significant number of species in the dry season. However, a lesser number of species and individuals were observed during the rainy season, which probably could be due to species migrating to escape the extreme cold weather of high-altitude during winters that stayed till March – April. Analysing the conservation status particularly, CITES Red List and the Convention on Migratory Status (CMS), revealed that the number of Red List species were almost similar in both seasons. However, the number of species listed in Appendix II of the CMS was comparatively higher in the dry season compared to the rainy season. Our field observation, particularly in the early April revealed higher migratory species.

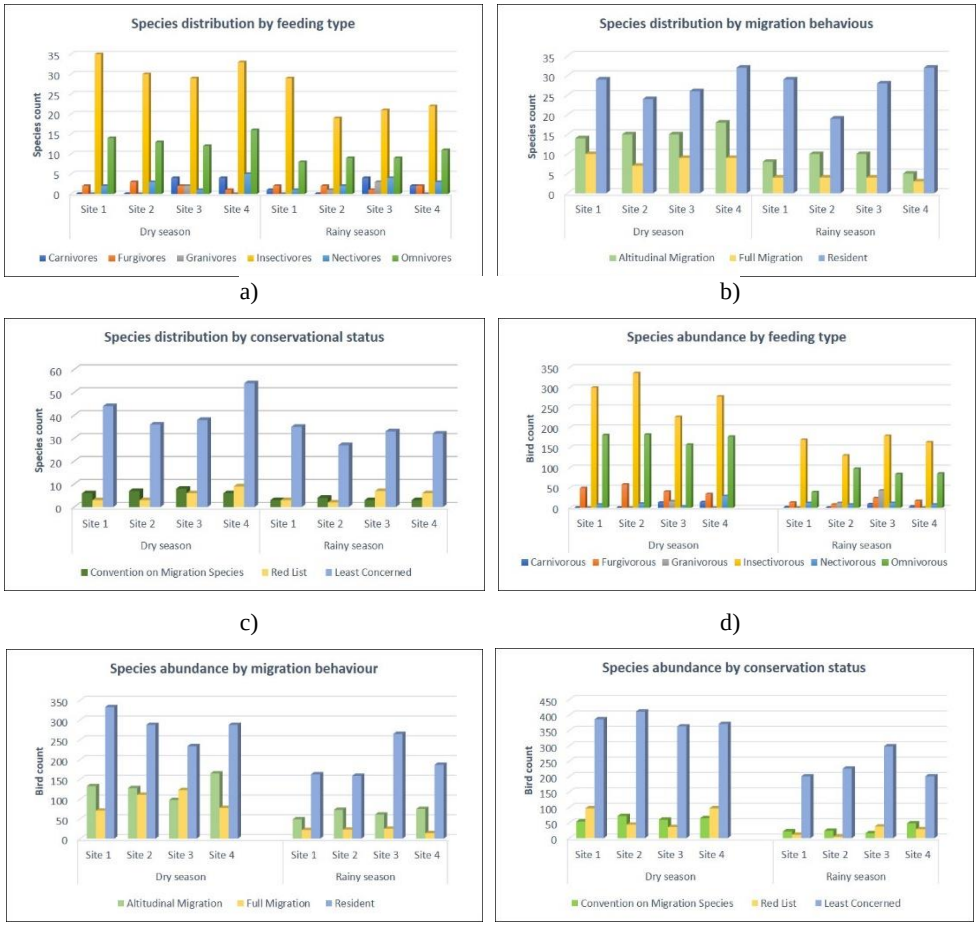

Figure 6. Species distribution by feeding, migration type and conservation status (a, b, c), and species abundance by feeding, migration type and conservation status (d, e, f).

Diversity indices

The diversity indices were compared between the dry and rainy seasons. While both the seasons displayed high avifauna diversity, the dry season tended to show better overall diversity, while rainy season had slightly better dominance and evenness, indicating more balanced species distribution. Specifically, in the dry season, the Shannon–Weiner index was 4.157, Simpson's index (1-D) was 0.979, the Dominance index (D) was 0.021, and the Evenness value was 0.710. In comparison, the rainy season had a Shannon–Weiner index of 3.896, Simpson's index (1-D) of 0.973, a Dominance index (D) of 0.027, and the Evenness value of

0.693. Similarly, diversity indices for all four sites were compared between two seasons (Table 4).

Table 4

Species richness and population, and diversity indices across four sites for dry and rainy season in Gangamaya Park

Parameters	Dry Season					Rainy Season				
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Total**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Total**
No. of species	53	46	50	59	90	41	33	42	40	71
Individuals	537	527	455	531	2050	234	255	351	276	1116
Diversity indices										
Shannon (H′)	3.661	3.586	3.619	3.777	4.157	3.546	3.268	3.432	3.453	3.896
Simpson (1-D)	0.966	0.965	0.964	0.972	0.979	0.965	0.953	0.959	0.961	0.973
Dominance (D)	0.034	0.035	0.036	0.028	0.021	0.035	0.047	0.041	0.039	0.027
Evenness (e^H/S)	0.734	0.784	0.746	0.74	0.71	0.846	0.796	0.737	0.79	0.693

The Shannon–Weiner index values, ranging from 3.586 to 3.777 in dry season, were higher across all sites compared to rainy season, where they ranged from 3.268 to 3.546. The Simpson's index (1-D) values were also higher in the dry season, ranging from 0.964 to 0.972 compared to the rainy season, which ranged from 0.953 to 0.965.

These results indicated higher bird diversity in the dry season, possibly due to the selection of pre- and post-monsoon months as dry season. The Dominance value in the dry season were lower across all sites, ranging from 0.028 to 0.036 compared to the rainy season, where they ranged from 0.035 to 0.047. The Evenness values in the dry season were also lower, ranging from 0.734 to 0.784, compared to 0.737 to 0.846 in the rainy season, although, Site 3 showed slightly higher value. In general, these results indicate a more balanced species distribution in the rainy season.

Overall, both seasons exhibit high bird diversity with relatively even distributions of species. The dry season shows slightly higher diversity, while the rainy season shows slightly higher evenness. The indices suggest that the biodiversity is well-distributed across the sites, with minor seasonal variations.

Statistical analysis

The species composition and abundance were compared using t-test for independent samples, assuming unequal variance between the dry and the rainy season (Table 5). The species composition showed a significant difference (p=0.008)

between dry season with mean of species and standard error of 52±2.04, compared to the rainy season (39±2.74). Similarly, there was a significant difference (p=0.001) in species abundance between the dry season (512.5 ± 19.27) and the rainy season (279 ± 25.48). The dry season showed significantly higher species composition and abundance compared to the rainy season, which is also confirmed by the diversity indices.

Table 5

Bird species composition and abundance compared between two seasons using t-test for independent samples assuming unequal variance

Parameters	**Dry season**		**Rainy season**		**t-value**	**p-value**
	Mean ± SE	**Variance**	**Mean ± SE**	**Variance**		
Species composition	52 ± 2.04	30	39 ± 2.74	16.66	2.447	0.008
Species abundance	512.5 ± 19.27	1486.33	279 ± 25.48	2598	2.44	0.001

Table 6

Bird abundance at four sites compared between dry and rainy seasons using t-test for independent samples assuming unequal variance

Sampling sites	**Dry season**		**Rainy season**		**t-value**	**p-value**
	Mean ± SD	**Variance**	**Mean ± SD**	**Variance**		
Riparian forest (Site 1)	10.13 ± 9.64	92.92	5.71 ± 4.48	20.06	2.95	0.002
Tea garden (Site 2)	11.45 ± 9.60	92.25	7.73 ± 6.49	42.1	2.06	0.021
Open woodland (Site 3)	9.1 ± 8.82	77.72	8.36 ± 7.67	58.77	0.43	0.333
Sub-tropical forest (Site 4)	9 ± 7.98	63.72	6.9 ± 5.79	33.53	1.52	0.66

A comparative t-test was performed to analyze bird species abundance between the dry and the rainy seasons across four sites (Table 6). The results showed a significant difference (p = 0.002) in species abundance at riparian forest in the dry season (10.13 ± 1.32) as compared to the rainy season (5.71 ± 1.04). Similarly, a significant difference (p = 0.021) was also observed for tea garden in dry season (11.45 ± 1.42) as compared to rainy season (7.73 ± 0.70).

However, open woodland and forest, showed no significant difference (p=0.333, and p= 0.66 respectively) in species abundance between the dry season (9.1 ± 1.25 for open woodland, and 9 ± 1.04 for forest) and the rainy season (8.36 ± 1.13 for open woodland, and 6.9 ± 0.92 for forest). These results suggest that birds are abundant in dry season in riparian forest and tea garden, possibly favoured by abundant food resource in habitats that are along the stream. In open woodland and forest, seasonal changes did not affect bird abundance.

DISCUSSION

Gangamaya Park exhibits significant bird species richness, with 93 species accounting for 20% of the bird species found in the Darjeeling Hills. The diverse land-use around the park area likely contributes to the richness. Although, the number of bird species in Gangamaya Park is low compared to 400 species listed in avibase database (last modified 18.03.2024) from Singalila National Park, 345 species from Lava in Neora Valley National Park. Similarly, the ebird database shows a list of 192 bird species from Chatakpur area in Senchal Wildlife Sanctuary, and 413 species from Latpanchar located in Mahananda Wildlife Sanctuary, considering the geographical area, it surpasses the number from study sites outside protected areas in Darjeeling-Sikkim Himalaya. For instance, in Darjeeling Hills, Chettri *et al.* (2018) recorded 48 species in the tea gardens of Kurseong. Similarly, Samanta *et al*. (2024) reported 72 species from Rongtong forest block. Ahmad & Yahya (2010) documented 130 species in the Makaibari tea garden. In the adjacent Sikkim Himalaya, 51 bird species were identified at two study sites in south Sikkim (Chettri *et al*., 2021a), and subsequently 59 bird species were recorded from the same region (Chettri *et al*., 2021b). Bhutia *et al*. (2020) reported 100 species in their preliminary survey of birds in south districts of Sikkim, including two wildlife sanctuaries from a similar elevational zone. These findings are significant, considering the size of Gangamaya Park and its location along the corridor of IBAs.

Among the 93 species recorded in the point count, 58% resides in the forest habitats, and 61% are insectivorous. These findings indicate forest cover promotes greater diversity of insect population, consequently bird species richness. A supportive study on avifauna diversity conducted by Joshi *et al.* (2021) in the Dehradun Valley in Uttaranchal, reported an increase in bird population due to abundance of insects in rich vegetation cover. Similar observations were recorded in the Ethopian highland, where birds communities move towards forest for feeding (Derebe *et al*., 2023; Asmare *et al*., 2023). Many of the recorded species display specialized feeding behaviours. For example, *Dicrurus hottentottus*, *Aethopyga* spp., exclusively feed on nectar, while *Cinclus pallasii*, *Motacilla cinerea*, *Turdus boulboul*, *Enicurus* sp., and *Phoenicurus* sp. forage along the stream, exhibiting unique foraging niches.

We found that 23.6% of the bird species documented are listed in the CITES and CMS as conservation priority species. These findings highlight the conservation and ecological significance of this areas.

Conservation efforts should focus on protecting the habitats, ensuring food availability, and providing quality habitat for both resident and migratory bird species to thrive. Although, *Leiothrix lutea* a common passerine of south-east Asia, they are included under CITES, yet it is reported as invasive in Britian (Broughton *et al*., 2022), *Pycnonotus cafer* a passerine introduced in the pacific island and now worldwide in distribution are reported as invasive, seriously impacting agriculture and spreading invasive plants through seed dispersal (Thibault *et al*., 2018).

Seasonal migration among birds is common, driven by availability of food resources and climatic conditions (Acharya *et al*., 2011; Somveille *et al*., 2020; Arya & Gopi, 2021).

The mountainous region of Darjeeling Hills is no different, with nearly 30.11% displaying altitudinal migration, while 19.35% of bird species showing full migration. These findings indicate that the Gangamaya Park, located in the mid-elevation, is a suitable feeding and or stopover site for a large number of full migratory birds, while for altitudinal migratory birds it is to avoid temperature fluctuation, an annual feature. Similar, seasonal migration pattern in response to resource bottleneck, temperature fluctuation, habitat condition, breeding cycle are reported in different parts of the Himalaya (Katuwal *et al*., 2016; Lee & Kang, 2019; Arya & Gopi, 2021). Additionally, climatic conditions such as change in the day length and light condition (Dixit & Singh, 2011) and precipitation regimes (Katuwal *et al*., 2016) have been reported to influence the migration pattern. Similarly, the presence of *Cuculus canorus* in Gangamaya Park indicates a suitable habitat for long distance migrants. Satellite telemetry studies on *Cuculus canorus* have found that the species travels to Europe for breeding from Central Africa in a cyclical loop (Willemoes *et al*., 2014; Sokolov *et al*., 2023).

Our study revealed that the bird diversity and evenness were comparatively high during the dry season than the rainy season. Similar trend, across habitats, suggest that the dry season provides a favourable environment for a higher number and greater diversity of species. Relatively higher species richness and diversity were also reported during the dry season in other parts of the Himalayan region (Katuwal *et al*., 2016; Nepali *et al*., 2022). This may be due to better visibility when birds move for foraging (Nepali *et al*., 2022) and their foraging niche, crucial for bird identification and count. Chettri *et al.* (2021c) reported, birds are most active at five m height above ground in the Sikkim Himalaya, which confirms to maximization of count. It was also noted that birds actively feed during clear days when there are ample preys. Additionally, during the rainy season, we observed that the birds do not come out to forage, and remain mostly silent. It also coincides with the breeding time, when most of the birds go for nesting, thereby reducing the bird count.

Our results indicated that bird species richness and abundance vary significantly ($p = 0.008$ and 0.001) between two seasons. The difference in the species richness and abundance may be due to availability of food resources, favourable weather conditions, and variability in the habitats. Similar studies in the Central Himalaya of Nepal by Katuwal *et al.* (2016) reported a significant increase in bird species from pre-monsoon through monsoon and autumn. Nepali *et al*. (2021) also observed difference between winter and summer, but observed higher species and diversity during the winters in the Kavrepalanchowk district, in Nepal. Additionally, a

supportive study by Basile *et al.* (2021) reported the importance of habitat structure and landscape context determining the abundance, species richness, and diversity of birds. The bird abundance varies significantly ($p = 0.002$ and 0.021) at certain sites between seasons, particularly in the riparian forest and tea gardens. In contrast, bird species richness and abundance in forest land and open woodland do not fluctuate much. This could be attributed to factors such as better availability of food resources, favourable weather conditions, or less competition during the dry season.

The stability in bird abundance in the tea garden and open woodland, may be due to consistent habitat condition, where resident populations adapt and forage in diverse habitats, thus not fluctuating significantly between seasons. A supportive study by Chettri *et al.* (2018) reported lower diversity in the tea gardens of Darjeeling.

CONCLUSION

Gangamaya Park located in the mid-elevation in Darjeeling Hills along the IBA corridor, exhibit extremely rich avifaunal diversity. This richness is attributed to the diverse land-use around the park, which supports a large number of migratory species, including conservation priority species.

The number of bird species in Gangamaya Park surpasses that of many study sites outside protected areas from Darjeeling-Sikkim Himalaya. Seasonal changes significantly influence the avian dynamics, with the dry season showing high species diversity, abundance and evenness compared to the rainy season.

The increased species richness and abundance during the dry season highlight the need for targeted conservation efforts during this period to support the larger and more diverse avifauna. Recognizing and addressing the differences in biodiversity between seasons is crucial for effective habitat management and conservation strategies.

These findings underscore the importance of incorporating seasonal considerations into biodiversity studies and conservation planning. Aligning conservation efforts with the natural fluctuations in species richness and abundance ensures effective management of bird habitats, promoting sustainability across different seasons. Understanding these patterns is essential in developing conservation strategies.

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*Corresponding author:
e-mail: barkrai@gmail.com
Department of Zoology
St. Joseph's College, Darjeeling
P.O North Point, Darjeeling, WB, India