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Cover: The critically endangered *Lilium polyphyllum* in watercolour and acrylics. © Aishwarya S Kumar.

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ARTICLE

Assessing and understanding diversity and foraging guilds of bird community structure in Gautam Buddha Wildlife Sanctuary, Bihar and Jharkhand, India

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Abstract: This study was conducted between June 2017 and December 2018 to assess the bird community structure, diversity, feeding guilds, and the residential status of birds in Gautam Buddha Wildlife Sanctuary (GBWS). Avian diversity and guild organization in five different habitat types were classified according to the forest type present in the landscape. The results indicated a total of 99 avifauna that belongs to 48 families, distributed in 16 orders. Among the 99 species, 77 were residents, 17 were winter visitors, four were summer visitors, and only one was a passage migrant. Based on the feeding guild evaluation, the majority were insectivorous (47%), followed by omnivorous (24%), carnivorous (14%), granivorous (8%), frugivorous (4%), insectivorous (1%), and piscivorous (1%). The scrubland, among other forest types, represented the highest diversity value for the Shannon-Weiner diversity index (3.2), evenness was recorded highest in riverine habitat (0.63), whereas utmost Simpson's dominance (0.98) and Fisher's index value (41) were in human settlement. These findings of our study illustrate the outstanding potential of GBWS as an important protected site for mixed bird diversity and specific feeding guilds, precisely in terms of the insectivorous and omnivorous communities. Hence, the study outcomes set a notable landmark for understanding birds and their habitats.

Keywords: Avifauna, evenness, Fisher's index, habitat types, protected site, residential status, Simpson's dominance, Shannon-Weiner diversity index.

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Author contributions: US—conceptualization, data collection, data analysis & visualization, methodology, writing the original draft. MA—conceptualization, writing original draft, data collection. VR—data collection. SAH—conceptualization, funding acquisition, investigation, supervision, writing - review & editing. RB—conceptualization, writing - review & editing.

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INTRODUCTION

Bird communities are considered to provide excellent model structures for studying biodiversity due to their occurrence in all habitat types and climatic zones (McCain & Grytnes 2010; Panda et al. 2021). Mixed habitats such as woodland, cropland, scrubland, riverine, and grasslands ensure the existence of habitat-restricted taxa and amplify community diversity (Berg 2002; Stein et al. 2014; Stein & Kreft 2015). Additionally, the diverse characteristics within natural environments and species diversity are pivotal in upholding essential traits that contribute significantly to biodiversity. (Manhães & Loures-Ribeiro 2005). Species diversity and richness in a particular area are determined by habitat heterogeneity and may also impact habitat resources (Lorenzón et al. 2016). At the same time, the absence of a natural environment leads to species homogenization with low species richness (Pickett et al. 2011; Lepczyk & Warren 2012; Aronson et al. 2014; Beninde et al. 2015) and high similarity (Blair 2001a,b). Bird diversity is always correlated with specific habitat types (Brawn et al. 2001; Seymour & Simmons 2008; Harisha & Hosetti 2009). Changes in their vegetation structure are affected by bird community structure and composition (Caziani & Derlindati 2000; Gabbe 2002; Earnst & Holmes 2012; Nsor et al. 2018), population trends, behaviour patterns, and reproductive ability (Harisha & Hosetti 2009). Vegetation structure is essential in structuring bird communities (Gabbe et al. 2002; Earnst & Holmes 2012); thus, the relative abundance of birds is often linked to vegetation community (Caziani & Derlindati 2000). For example, MacArthur & MacArthur (1961) pointed out the importance of vegetation structure for local bird species diversity. Williams (1964) highlighted that various environmental conditions and habitat types increase with an increase in the study area.

Feeding guild is a fundamental concept in avian ecology and is shaped when a community of birds uses the same class of environmental resources (Balestrieri et al. 2015). Katuwal et al. (2016) stated that all guilds have different resource requirements and tolerance capacities depending on ecological conditions, which are influenced by various environmental factors such as vegetation cover, food supply, predatory availability, and various other ecological factors reflecting different temporal variations and diversity gradients (O'Connell et al. 2000; Kissling et al. 2012). Studies of avian feeding guilds help to understand complex ecosystem structures and improve knowledge about the habitats of a particular ecosystem (Rathod & Padate 2017).

The distribution and feeding guild of the birds is associated with their habitat type and structural complexity, which influence species diversity and the inter-relationship between vegetation and the avian population (MacArthur & MacArthur 1961). Many studies have been conducted to determine relationships between bird species diversity and habitat attributes such as heterogeneity and vegetation structure (Chettri et al. 2005; Corbett 2006; Yeany 2009; Beasley 2013; Stirnemann et al. 2015). Bird populations in fragmented landscapes respond resiliently to complex environmental combinations and are an indicator of habitat change, and they also show a wide range of feeding guilds (Azman et al. 2011). Protected areas with substantial anthropogenic disturbance causes habitat fragmentation and degradation (Haddad et al. 2015; Wilson et al. 2016; Pardini et al. 2017).

In the Gautam Buddha Wildlife Sanctuary (GBWS), over the past few years, the widening of the National Highway (NH-2) has split the sanctuary into two halves. Moreover, anthropogenic pressures, selective hunting, and the expansion of villages in and around the sanctuary have been significant causes of biodiversity decline (Kumar 2016). The study of bird diversity and feeding guilds is crucial for understanding the complexity of ecosystem structure and for providing up-to-date knowledge on each habitat type in the ecosystem. In addition, we have also assessed the abundance of birds in the various habitat types. Thus, the present study aimed to understand the diversity of birds and feeding guilds with different habitat types, such as woodland, scrubland, human settlement, riverine, and cultivation lands. The study will also provide baseline information on the bird community's species richness, which will help design management plans and conservation strategies for the sanctuary.

Study area

The GBWS lies between 24.379°–24.425° N and 85.136°–85.213° E and is situated in the southeast part of the sacred city of Gaya district, Bihar. The sanctuary spreads over an area of 259.47 km^2 in the states of Bihar and Jharkhand under three forest divisions: the Gaya Forest Division (138.33 km^2) in Bihar and the Hazaribagh and Chatra Forest Division (121.24 km^2) in Jharkhand (Figure 1). The Bihar government notified the sanctuary in 1976. Before becoming a sanctuary, it used to be the hunting ground of the Tikri king. The terrain of the sanctuary is undulating, with an elevation ranging 213–529 m. The sanctuary is drained by the perennial river Mohane, a sink for all the streams and rivulets flowing in

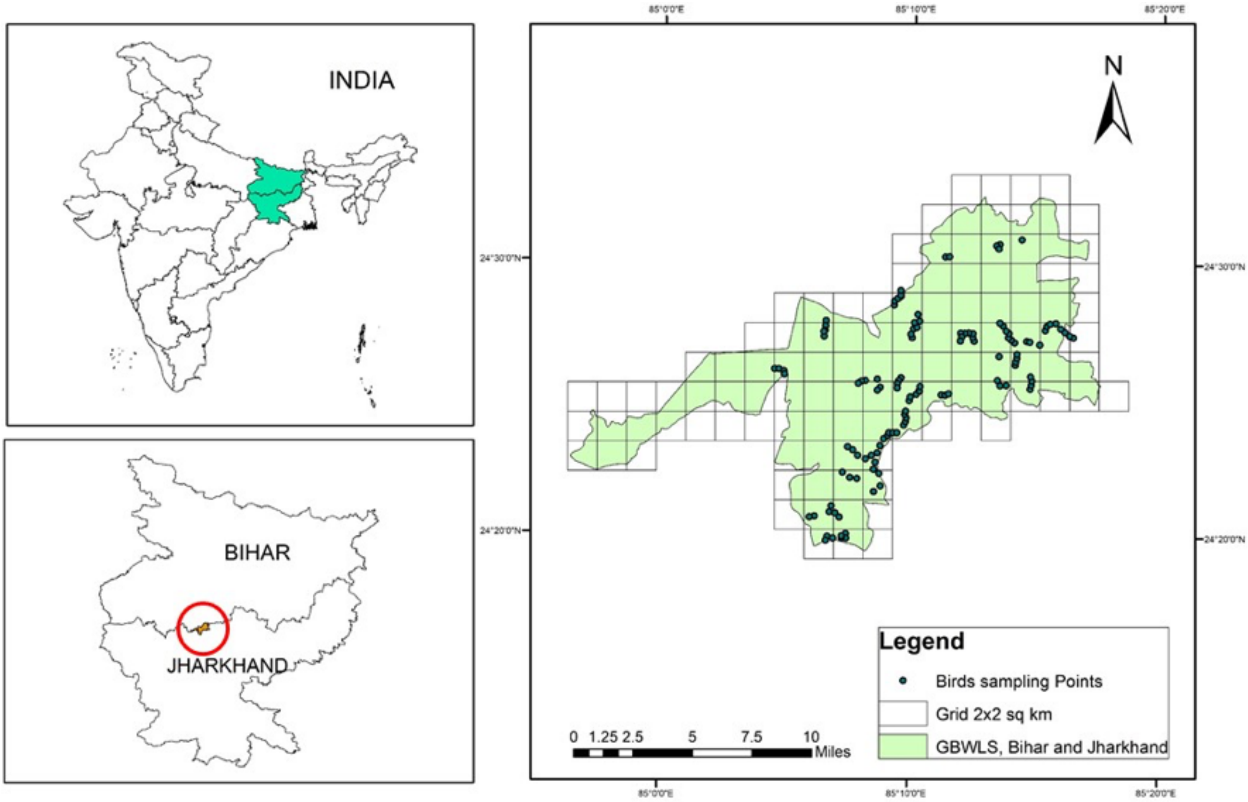

Figure 1. The study area of Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

the sanctuary (Kumar 2016). The south-west monsoon starts in June and lasts until September. Rainfall is highest between June and July, with an average rainfall of 159 mm. The average temperature varies 26–9^{0}C during the winter season, which commences from November to February (Nirbhay & Singh 2009). The average summer temperature ranges around 40^{0}C maximum, even touching 47^{0}C, and is usually characterized by dry and hot weather conditions from March to June.

The sanctuary falls in the lower Gangetic Plains and Chota Nagpur biogeographical regions of India and shares wildlife species from both regions. Making it a unique ecosystem that supports a wide diversity of floral and faunal species (Rodgers & Panwar 1988; Kumar 2016; Kumar et al. 2021). The sanctuary is characterized by moist and dry deciduous forests (Kumar et al. 2021). Forest communities are further divided into dry peninsular sal forest, northern dry mixed deciduous forest, dry deciduous scrub forest, ravine thorn forest, and tropical dry riverine forest (Kumar 2016; Kumar & Sahu 2020). More than 100 species of plants and 75 species of birds enrich the biodiversity of the sanctuary (Kumar et al. 2021). Various dominant flora of the sanctuary comprises *Shorea robusta*, *Pterocarpus marsupium*, *Diospyros melanoxylon*, *Lagerstroemia parviflora*, *Buchanania lanzan*, *Butea monosperma*, *Madhuca indica*, *Acacia catechu*, and *Boswellia serrata*. It also supports various wild animal species, such as *Axis axis*, *Rusa unicolor*, *Melursus ursinus*, *Boselaphus tragocamelus*, *Vulpes bengalensis*, and *Felis chaus*, among others (Kumar 2016).

METHODS AND MATERIALS

Data collection

The avifaunal status, habitat characteristics, and community structure were assessed using the point count transect method during summer (June–August 2017) and winter (November–December 2018). Bird observations occurred from 0700 h to 1000 h, avoiding adverse weather conditions (Ding et al. 2019). A 1-km trail transect with five observation points at 250 m intervals was used, involving two observers. Within a 50-m radius during a 15-minute duration, bird species, distances, and individual numbers were recorded. Birds flying overhead of the observer were not recorded to avoid the double count. The birds were observed with the help of Nikon (8x10) binoculars, and photographs were taken using a Cannon 80D camera for further identification. The birds were identified with the help of Grimmett et al. (2016).

Guild classification

In this study, birds were systematically categorized into distinct feeding guilds based on their primary diet and foraging habitats, following the classification outlined by Ding et al. (2019) and Panda et al. (2021). The seven identified guild categories are as follows: insectivores (species consuming insects, earthworms, small crustaceans, and arthropods), carnivores (species preying on large animals or scavenging their carcasses), omnivores (species with a mixed diet of both animals and plants), granivores (species primarily feeding on seeds and grains), nectarivores (species relying on nectar as a primary food source), frugivores (species mainly consuming fruits), and piscivores (species specialized in a fish-based diet). This classification scheme provides a comprehensive framework for understanding the diverse dietary preferences and foraging behaviors exhibited by avian species within the studied ecosystem.

Data analysis

In the data analysis phase, various species diversity indices were computed using the Paleontological Statistics (Past 2001 version 3.2) program (Hammer & Harper 2001). Shannon's diversity index (H) was employed to assess community diversity, calculated using the formula $H = -\sum(p_i \ln p_i)$, where pi represents the proportion of individuals of a particular species with the total number of individuals (n/N), and s is the number of species. Simpson's index (D), a dominance measure, was also utilized, given by the formula $1/(\sum(p_i^2))$, where pi is as defined for Shannon's index. Fisher alpha (S) was employed to mathematically describe the relationship between species and individuals, expressed as $S = \alpha \times \ln(1 + n/a)$, with S denoting the number of taxa, n representing the number of individuals, and α as Fisher's alpha (Fisher & Yates 1953). Evenness (e), comparing actual diversity to maximum potential diversity, was determined using $e = H'/H_{max}$, with E constrained between 0 and 1. Relative abundance (RA) of each bird species was calculated as $n_i/N \times 100$, with ni being the number of individuals of the ith species and N being the total number of individuals. Abundance categories were assigned based on sightings, from rare (1–5) to very abundant (>50). The Sorensen similarity index (Cs) gauged species association between habitats using $Cs = 2j/(a + b)$, where j is the number of common species, a is the number of species in habitat A, and b is the number of species in habitat B. Bird residential status categories (resident, summer visitor, winter visitor influx) were determined using the presence and absence method (Sorensen 1948). Statistical analyses were conducted in SPSS, with significance at $p = 0.01$. Pearson's correlation (r) explored relationships between guilds, residential status, and habitat types, and post-hoc Wald tests with Bonferroni adjustments were performed for identified significant differences. Additionally, a one-way analysis of variance (ANOVA) examined significant differences in habitat-related species richness concerning feeding guilds and residential status.

RESULTS

The present study recorded 99 avifaunal species belonging to 16 orders and 48 families in GBWS. Amongst the habitats, the highest species richness was recorded in woodland (53.52%), and the lowest species richness was recorded in cultivation land (20.20%) (Table 1). The highest number of species belongs to the order Passeriformes (52.52%), followed by Accipitriformes and Charadriiformes (Figure 2). The species diversity of birds in five different habitats of the study area revealed that the highest Shannon diversity was recorded in scrubland (H = 3.186), followed by woodland (H = 3.181) and human settlement (H = 3.136). In contrast, the lowest Shannon diversity was recorded in cultivation land (H = 2.527). The Simpson diversity index value was maximum in human settlement (1-D = 0.978) and minimum in woodland (1-D = 0.926). The Evenness of bird species was highest in the riverine (0.629) and lowest in the woodland forest (0.454) (Table 1). At a 95% confidence interval level, we found that scrubland possesses the highest holding capacity of diversity compared to the other habitats. The Fisher alpha diversity index was highest in human settlement (α = 41.12). The lowest Fisher alpha diversity profile was recorded in cultivation land (α = 16.47) (Figure 3).

According to the frequency of sightings, 68.68% of bird species were rare, and 1.01% were abundant in GBWS (Figure 4). The relative abundance of Red-vented Bulbul *Pycnonotus cafer* was highest in the study area, followed by Jungle Babbler *Turdoides striata* and Grey-breasted Prinia *Prinia hodgsonii* (Appendix 1). Results of Sorenson's similarity index indicate that woodland and scrubland (0.31) were ecologically the most similar habitats, followed by the similarity between woodland and human settlement (0.30). However, riverine and

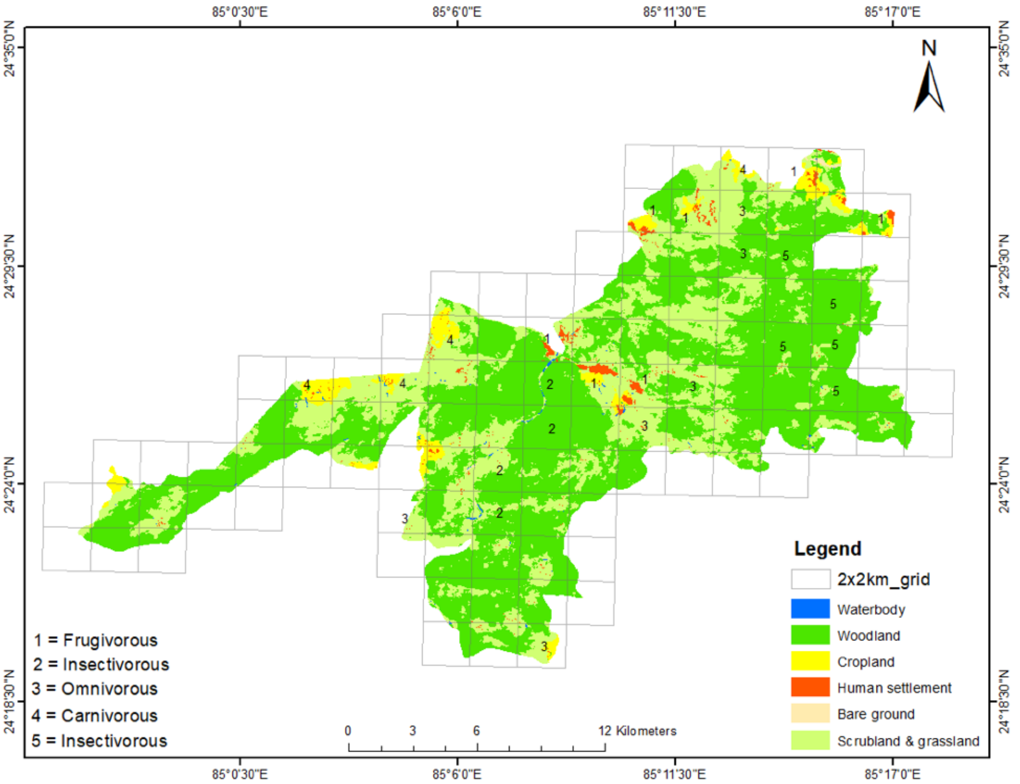

Figure 2. Land use Land cover of Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

Table 1. Percentage, feeding guild, diversity, and dominance of birds in different habitats in GBWS Bihar and Jharkhand.

	Habitat	Number of species	Percentage	Feeding guild	Shannon diversity	Simpson (1-D)	Evenness	Fisher alpha
1	Woodland	53	53.53	6	3.181	0.926	0.454	17.26
2	Scrubland	47	47.47	7	3.186	0.950	0.514	24.83
3	Riverine	32	32.32	5	3.003	0.960	0.629	19.77
4	Human settlement	37	37.37	6	3.136	0.978	0.621	41.12
5	Cultivation land	20	20.20	5	2.527	0.947	0.625	16.47

woodland had the most negligible ecological similarity value (0.14) (Table 3).

Further, the bird species were categorized according to their feeding guild. Among the feeding guilds, the insectivorous guild recorded a maximum percentage of species (47.47%), and nectarivores and piscivorous guild recorded a minimum percentage of species (1.01%) (Figure 5). Regardless of the habitats, the dominant guild remained the insectivorous among all the guilds. The comparison of the abundance of species from all habitats within every feeding guild is shown in Table 2.

The Pearson correlation coefficient provided visions of the specific preference of the bird species under different foraging guild towards some particular habitats. The frugivorous guild was most positively correlated with human settlement ($r = 0.282$, $t = 0.320$ $p < 0.01$), and negatively with cultivation ($r = -0.29$, $t = 1.988$, $p > 0.01$), riverine ($r = -0.102$, $t = 2.267$, $p > 0.01$), and scrubland ($r = -0.045$, $t = 2.021$, $p > 0.01$). Insectivorous bird species were only positively correlated with the riverine habitat ($r = 0.127$, $t = 8.037$ $p < 0.01$) and negatively correlated with the remaining habitats. Omnivores were most positively correlated with scrubland habitat ($r = 0.156$, $t = 4.459$ $p < 0.01$) and a negative correlation with riverine habitat ($r = -0.150$, $t = 1.9885$, $p < 0.01$). On the other hand, the carnivorous guild was strongly associated with cultivation habitat ($r = 0.128$, $t = 3.295$ $p < 0.01$). Granivores showed a positive association with only scrubland habitat ($r = 0.105$, $t = 2.038$ $p < 0.01$).

Further, the residential status of the species revealed

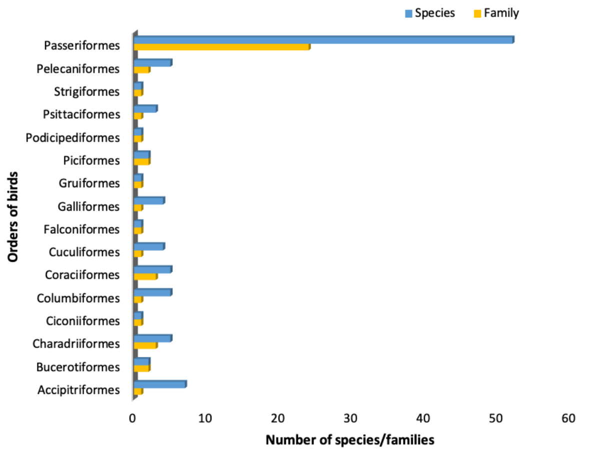

Figure 3. Composition of avian community in Gautam Buddha Wildlife Sanctuary Bihar & Jharkhand.

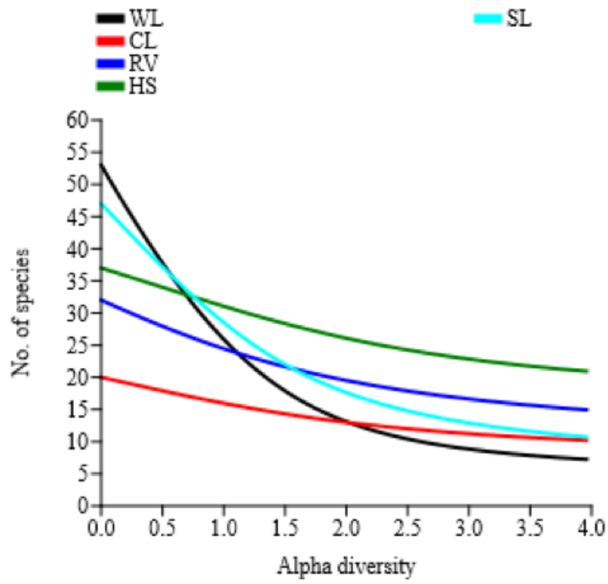

Figure 4. Species diversity profile of bird species in different habitats of Gautam Buddha Wildlife Sanctuary.
WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

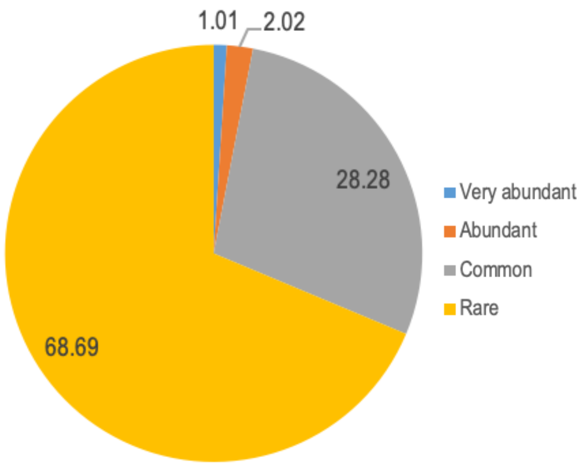

Figure 5. The pie chart shows the percentage of bird species in different abundance categories in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

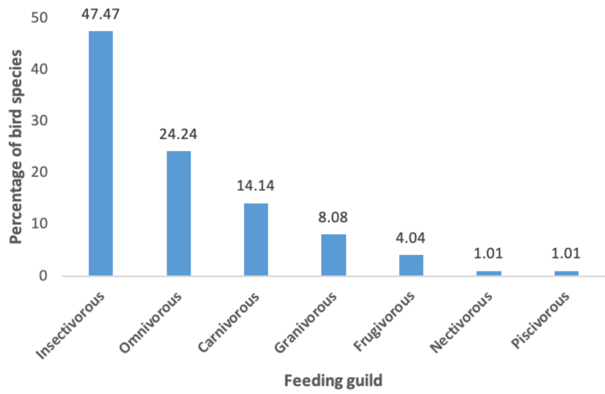

Figure 6. Percentage of the bird community in different feeding guilds observed in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

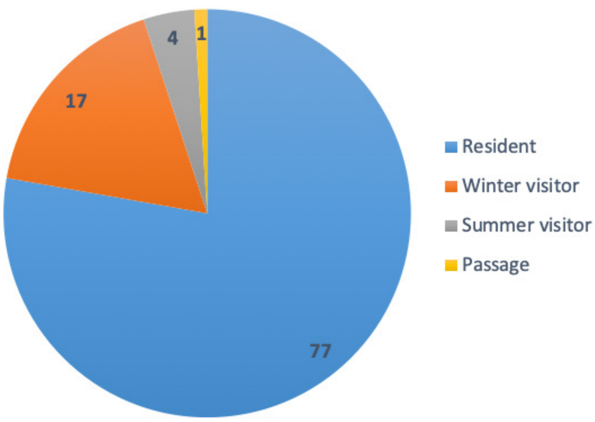

Figure 7. The pie chart shows the number of birds under different residential statuses in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

that 77 birds were residents, whereas the remaining 17 were winter visitors, four were summer visitors, and one species was a passage migrant (Figure 6). While analyzing the association of different habitats according to their residential status, we found that resident bird species were positively correlated with all the habitat types, but the association was highest with scrubland ($r = 0.177$, $t = 16.226$ $p < 0.01$). It was discovered that there was no significant correlation between any of the habitat categories and summer visitors, winter visitors, or passage migrants.

DISCUSSION

The bird diversity and their distribution concerning habitat types characterize the importance of GBWS as an essential bird habitat. The present study revealed that Passeriformes was the dominant order comprising the highest number of bird species. Two species represented the order Bucerotiformes and Piciformes; besides the order Ciconiiformes, Falconiformes, Gruiformes, Podicipediformes, and Strigiformes were represented by single species. This study agrees with the prior result that order Passeriformes is the leading avian taxon in India (Praveen et al. 2016; Kumar & Sahu 2020; Singh 2022). Data analysis on relative abundance shows that the Accipitridae family is the most dominant one. A similar pattern of dominance of Accipitridae was recorded by different authors from different protected areas in India, for example, from the Araku Valley of Ananthagiri Hills of the Eastern Ghats in Visakhapatnam, Andhra Pradesh (Kumar et al. 2010), a scrub forest of Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh (Mali et al. 2017), Tamhini Wildlife Sanctuary, the northern Western Ghats, Maharashtra (Vinayak & Mali 2018), and Bhimbandh Wildlife Sanctuary, Bihar (Khan & Pant 2017).

The GBWS comprises a mosaic habitat, which supports a significant diversity of bird species. Habitat heterogeneity favors habitat specialists (through niche partitioning) for birds with broad niches (Surasinghe et al. 2010; Chakdar et al. 2016). The overall Shannon diversity index (H = 3.935) of GBWS is high. Therefore, the Shannon diversity in all habitats was good except in cultivation land (H = 2.527). The habitat heterogeneity hypothesis suggests that a landscape's species diversity increases with the number of habitats because of an expansion in the number of partitionable niche dimensions (Cramer & Willing 2005; Chakdar et al. 2016). Numerous studies have revealed that the distribution and diversities of bird species were highly dependent on habitat heterogeneity (Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018; Panda et al. 2021; Thilakarathne et al. 2021).

As the Simpson diversity index has swift convergence to limit diversity value for a minor sample size, it is principally suitable for rapidly estimating regions for conservation (Lande et al. 2000). Analysis of data on the Simpson dominance index revealed that human settlement (1-D = 0.978) was the most dominated habitat in the sanctuary followed by riverine habitat (1-D = 0.960). The high value of Simpson's index of diversity is an indication of the richness of bird diversity in the GBWS. The result revealed that bird species' Evenness varied in the sanctuary's different habitats. The highest evenness index value was recorded in the riverine habitat. Several reasons, including food availability, breeding, migration, and change in vegetation cover, could be attributed to this pattern (Harisha & Hosetti 2009). However, the lowest evenness index value recorded in woodland habitat expresses that the species-rich site may result from the occurrence of rare species or two or three species being hyper-abundant in the area compared to the other sites (Symonds & Johnson 2008).

However, the Fisher alpha diversity index was highest in human settlement (α = 41.12), as the number of individuals was low compared to the species number. In woodland habitats, the species diversity is highest, but due to the presence of more individuals of the bird species, Fisher's alpha was lower (α = 17.26) than in human settlement. The lowest Fisher alpha diversity profile was recorded in cultivation land (α = 16.47) (Figure 3). The diversity, which compares the similarity between habitats, is measured by Sorensen's similarity index between the five selected habitats. The result revealed that woodland and scrubland had the highest similarity value (0.31), while the lowest species similarity (0.14)

Table 2. Species presence at all habitats of each feeding guild.

Feeding guild	Habitat					Number of species
	WL	RV	H	CL	SL	
Carnivorous	7	5	3	4	3	15
Frugivorous	4	0	2	1	2	4
Granivorous	3	1	3	0	6	7
Insectivorous	27	20	16	9	19	47
Nectivorous	1	0	1	1	1	1
Omnivorous	11	5	12	5	15	24
Piscivorous	0	1	0	0	1	1
Number of species	53	32	37	20	47	

WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

Table 3. Sorenson's similarity index value between different habitats.

	Habitat	WL	CL	RV	HS	SL
1	SL	0.31	0.22	0.17	0.26	
2	HS	0.30	0.17	0.20		
3	WB	0.14	0.21			
4	RV	0.21				
5	WL					

WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

Image 1. Dhodiya village situated inside the Gautam Buddha Wildlife Sanctuary.

Image 2. Livestock rearing and grazing in the Gautam Buddha Wildlife Sanctuary.

Image 3. Cutting of trees in Gautam Buddha Wildlife Sanctuary.

was recorded between woodland and riverine habitats. The highest value of Sorensen's similarity indices documented between woodland and scrubland habitats might be attributed to landscape characteristics. Better habitat structural similarity tended to support more similar bird communities (Tubelis & Cavalcanti 2001; Andrade et al. 2018; Kumar & Sahu 2020).

Correlation values between different feeding guilds and habitat preferences displayed that the frugivorous bird population flourished well in the area with human settlement due to the sufficient availability of food sources. Gomes et al. (2008) have shown that resilient frugivores that increased in densities have occurred under all habitat disturbance regimes of the forest area, which markedly supports our study. In another study (Pejchar et al. 2008), frugivore abundance and richness were found to strongly account for a positive relationship with the human-dominated landscape. These results account for the fact that frugivores can tolerate moderate to intermediate levels of disturbance.

The significant positive correlation of insectivores was highest with riverine habitat. Other studies supporting the observation state that in wetlands, aquatic insects classically dominate the macroinvertebrate communities (Maher 1984; Euliss & Grodhaus 1987; Batzer & Resh 1992; Mukhopadhyay & Mazumdar 2019) and are an integral part of various aquatic ecosystems (Sivaramakrishnan et al. 2000). Omnivores and granivores were most favorable and significantly correlated with the scrubland habitat due to the mosaic structure of the habitat of GBWS. This contrasts with the findings of Mukhopadhyay & Mazumdar (2019), in a suburban landscape of the lower Gangetic plains of West Bengal, where the omnivores mostly dominated the residential and plantation forest area. Panda (2021) has also found a significant close association between human habitation with omnivores.

Additionally, granivores are positively related to the scrubland area, Poulin et al. (1993), support and validate our outcomes as they found a peak number of granivores interactions in the scrubland of the Guarapo region on the Araya Peninsula. In contrast, other studies support the preference of granivores for low-stratification crops (Henderson et al. 2000) and the positive relation with orchards due to the protection these areas offer from predation by birds of prey (Figueroa & Corales 2005). Furthermore, our study revealed that carnivorous species were primarily observed in cultivated forest areas due to the enormous presence of small size of frogs, fishes, molluscs, and small vertebrate species. Likewise, Tanalgo et al. (2015) agree with our study that carnivorous species were primarily observed in the rice fields. Stafford et al. (2010) indicated that the abundance of carnivorous bird species in rice fields is due to the availability of a large number of food resources, such as polychaetes, crustaceans, and molluscs. Besides, King et al. (2010) also noted that the rice fields in many countries support large numbers of migratory water birds and are essential for many species.

A significant positive correlation of the resident bird species with all the habitat types shows that these species are well distributed in the GBWS, but they mostly prefer the scrubland area. A study by Daily et al. (2001) also suggests that bird species mainly were correlated with the forest fragments. The migratory bird species do not possess any significant positive correlation with the different habitats. This is because migrants distribute themselves spatially and temporally relative to available fruit resources at different intervals (Wolfe et al. 2014).

Moreover, human interference and livestock pressure significantly threatened bird species in the sanctuary (Image 1,2). The presence of livestock in bird habitats caused a significant negative impact on the abundance and species richness of bird species ($r = -0.308$, $p = <0.01$). After agriculture, local inhabitants also depend on the sanctuary for livestock grazing. Overgrazing led to the destruction of plant seedlings and restricted forest regeneration. Studies by Adhikari et al. (2019) support our finding as they have also found that livestock pressure and human disturbances were the major threats to birds in Chitwan National Park. The presence of local people in the forested land caused a non-significant negative impact on bird species richness and abundance in the sanctuary ($r = -0.091$, $p = >0.01$). Another major cause of disturbance in bird habitat is the cutting of trees for fodder and fuelwood collection (Image 3). The Pearson correlation coefficient value of tree cutting was negatively not significant to habitat ($r = -0.064$, $p = >0.01$). These pragmatic findings suggest a negative impact of livestock and human interference on the bird species richness and abundance.

CONCLUSION

The present study is the first documentation of the bird diversity, richness, and feeding guilds found in GBWS. Our study concludes with evidence that GBWS is an essential habitat for birds with high conservation status.

The diversity of bird species recorded is highest in the scrubland habitat and lowest in the cultivation habitat. However, these habitats are under constant threat of high risk for immense anthropogenic pressure. Also, if human disturbance increases at the same pace, there would be the threat of homogenization of avian species, as these generalist species have the advantage over the specialists in disturbed ecosystems. Consequently, the study suggests that maintaining heterogeneous habitats could be a better strategy for the long-term survival of resident and migratory birds in GBWS.

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Appendix 1. Systematic checklist and status of birds recorded in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand, India.
LC—Least Concern | EN—Endangered | NT—Near Threatened | WV—Winter visitor | R—Resident | SV—Summer visitor | PM—Passage migrant.

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
1	Accipitriformes	Accipitridae	Black Eagle	*Ictinaetus malaiensis*	LC	0.61	WV	Carnivores
2			Black Kite	*Milvus migrans*	LC	0.15	R	Carnivores
3			Black-winged Kite	*Elanus caeruleus*	LC	0.61	R	Carnivores
4			Booted Eagle	*Hieraaetus pennatus*	LC	0.30	WV	Carnivores
5			Egyptian Vulture	*Neophron percnopterus*	EN	0.46	R	Carnivores
6			Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	0.30	R	Carnivores
7			Shikra	*Accipiter badius*	LC	0.46	R	Carnivores
8	Bucerotiformes	Bucerotidae	Indian Grey Hornbill	*Ocyceros birostris*	LC	0.46	R	Frugivores
9		Upupidae	Common Hoopoe	*Upupa epops*	LC	0.46	R	Insectivores
10	Charadriiformes	Turnicidae	Barred Buttonquail	*Turnix suscitator*	LC	2.44	R	Omnivores
11		Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	LC	1.07	WV	Insectivores
12		Charadriidae	Little-ringed Plover	*Charadrius dubius*	LC	0.46	R	Insectivores
13			Red-wattled Lapwing	*Vanellus indicus*	LC	0.30	R	Insectivores
14			Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	0.61	R	Insectivores
15	Ciconiiformes	Ciconiidae	Asian Openbill	*Anastomus oscitans*	LC	0.30	R	Carnivores
16	Columbiformes	Columbidae	Rock Pigeon	*Columba livia*	LC	0.30	R	Granivores
17			Spotted Dove	*Streptopelia chinensis*	LC	2.74	R	Granivores
18			Eurasian Collared Dove	*Streptopelia decaocto*	LC	0.30	R	Granivores
19			Laughing Dove	*Streptopelia senegalensis*	LC	0.30	R	Granivores
20			Orange-breasted Green Pigeon	*Treron bicinctus*	LC	0.76	R	Granivores
21	Coraciiformes	Coraciidae	Indian Roller	*Coracias benghalensis*	LC	0.91	R	Insectivores
22		Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	LC	0.91	R	Piscivores
23		Meropidae	Chestnut-headed Bee-eater	*Merops leschenaulti*	LC	1.37	R	Insectivores
24			Green Bee-eater	*Merops orientalis*	LC	2.74	R	Insectivores
25			Blue-tailed Bee-eater	*Merops philippinus*	LC	0.91	SV	Insectivores
26	Cuculiformes	Cuculidae	Greater Coucal	*Centropus sinensis*	LC	0.61	R	Omnivores
27			Jacobin Cuckoo	*Clamator jacobinus*	LC	0.30	SV	Insectivores
28			Asian Koel	*Eudynamys scolopaceus*	LC	0.46	R	Omnivores
29			Common Hawk-cuckoo	*Hierococcyx varius*	LC	0.76	R	Omnivores
30	Falconiformes	Falconidae	Common Kestrel	*Falco tinnunculus*	LC	0.15	WV	Carnivores
31	Galliformes	Phasianidae	Grey Francolin	*Francolinus pondicerianus*	LC	0.91	R	Omnivores
32			Painted Spurfowl	*Galloperdix lunulata*	LC	0.61	R	Omnivores
33			Red Junglefowl	*Gallus gallus*	LC	0.61	R	Omnivores
34			Indian Peafowl	*Pavo cristatus*	LC	0.15	R	Omnivores
35	Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	0.30	R	Insectivores
36	Passeriformes	Sturnidae	Jungle Myna	*Acridotheres fuscus*	LC	0.61	R	Omnivores
37		Sturnidae	Common Myna	*Acridotheres tristis*	LC	3.50	R	Omnivores
38		Aegithinidae	Common Iora	*Aegithina tiphia*	LC	0.15	R	Insectivores
39		Motacillidae	Paddyfield Pipit	*Anthus rufulus*	LC	0.15	R	Insectivores

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
40	Passeriformes	Motacillidae	Tree Pipit	*Anthus trivialis*	LC	0.15	WV	Insectivores
41		Chloropseidae	Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	0.46	R	Omnivores
42		Sylviidae	Yellow-eyed Babbler	*Chrysomma sinense*	LC	1.37	R	Insectivores
43		Nectariniidae	Purple Sunbird	*Cinnyris asiaticus*	LC	2.28	R	Nectivores
44		Muscicapidae	Indian Robin	*Copsychus fulicatus*	LC	2.59	R	Insectivores
45		Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	LC	2.13	R	Insectivores
46		Campephagidae	Large Cuckooshrike	*Coracina macei*	LC	0.61	R	Insectivores
47		Corvidae	Large-billed Crow	*Corvus macrorhynchos*	LC	0.46	R	Omnivores
48		Corvidae	House Crow	*Corvus splendens*	LC	0.30	R	Omnivores
49		Muscicapidae	Tickell's Blue Flycatcher	*Cyornis tickelliae*	LC	0.15	WV	Insectivores
50		Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	LC	1.67	R	Omnivores
51		Dicaeidae	Thick-billed Flowerpecker	*Dicaeum agile*	LC	0.61	R	Omnivores
52		Dicruridae	White-bellied Drongo	*Dicrurus caerulescens*	LC	0.30	R	Insectivores
53		Dicruridae	Ashy Drongo	*Dicrurus leucophaeus*	LC	0.30	WV	Insectivores
54		Dicruridae	Black Drongo	*Dicrurus macrocercus*	LC	2.74	R	Insectivores
55		Alaudidae	Ashy-crowned Sparrow-lark	*Eremopterix griseus*	LC	0.46	R	Omnivores
56		Estrildidae	Indian Silverbill	*Euodice malabarica*	LC	0.46	R	Granivores
57		Muscicapidae	Taiga Flycatcher	*Ficedula albicilla*	LC	0.15	WV	Insectivores
58		Sturnidae	Asian Pied Starling	*Gracupica contra*	LC	1.37	R	Omnivores
59		Laniidae	Brown Shrike	*Lanius cristatus*	LC	0.30	WV	Insectivores
60		Laniidae	Long-tailed Shrike	*Lanius schach*	LC	0.91	WV	Insectivores
61		Laniidae	Bay-backed Shrike	*Lanius vittatus*	LC	0.15	R	Insectivores
62		Estrildidae	Scaly-breasted Munia	*Lonchura punctulata*	LC	0.91	R	Granivores
63		Alaudidae	Indian Bush Lark	*Mirafra erythroptera*	LC	0.30	R	Omnivores
64		Motacillidae	White Wagtail	*Motacilla alba*	LC	0.30	WV	Insectivores
65		Motacillidae	Grey Wagtail	*Motacilla cinerea*	LC	0.15	WV	Insectivores
66		Muscicapidae	Brown Rock Chat	*Oenanthe fusca*	LC	0.30	R	Insectivores
67		Oriolidae	Indian Golden Oriole	*Oriolus kundoo*	LC	0.61	R	Insectivores
68		Cisticolidae	Common Tailorbird	*Orthotomus sutorius*	LC	0.46	R	Insectivores
69		Sturnidae	Rosy Starling	Pastor roseus	LC	0.15	PM	Omnivores
70		Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC	0.76	R	Insectivores
71		Muscicapidae	Black Redstart	*Phoenicurus ochruros*	LC	0.15	WV	Insectivores
72		Phylloscopidae	Tickell's Leaf Warbler	*Phylloscopus affinis*	LC	0.15	WV	Insectivores
73		Phylloscopidae	Hume's Leaf Warbler	*Phylloscopus humei*	LC	0.15	WV	Insectivores
74		Phylloscopidae	Greenish Warbler	*Phylloscopus trochiloides*	LC	0.76	WV	Insectivores
75		Pittidae	Indian Pitta	*Pitta brachyura*	LC	0.30	SV	Insectivores
76		Cisticolidae	Grey-breasted Prinia	*Prinia hodgsonii*	LC	4.41	R	Insectivores
77		Cisticolidae	Plain Prinia	*Prinia inornata*	LC	0.46	R	Insectivores
78		Cisticolidae	Ashy Prinia	*Prinia socialis*	LC	0.15	R	Insectivores
79		Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	LC	16.74	R	Omnivores
80		Pycnonotidae	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	0.30	R	Omnivores
81		Rhipiduridae	White-browed Fantail	*Rhipidura aureola*	LC	0.61	R	Insectivores
82		Sturnidae	Brahminy Starling	*Sturnia pagodarum*	LC	0.15	R	Omnivores

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
83	Passeriformes	Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC	1.22	R	Insectivores
84		Vangidae	Large Woodshrike	*Tephrodornis virgatus*	LC	0.30	R	Insectivores
85		Monarchidae	Indian Paradise Flycatcher	*Terpsiphone paradisi*	LC	1.07	SV	Insectivores
86		Leiothrichidae	Jungle Babbler	*Turdoides striata*	LC	5.94	R	Insectivores
87		Zosteropidae	Oriental White-eye	*Zosterops palpebrosus*	LC	1.83	R	Insectivores
88	Pelecaniformes	Ardeidae	Great Egret	*Ardea alba*	LC	0.15	R	Carnivores
89			Indian Pond Heron	*Ardeola grayii*	LC	0.76	R	Carnivores
90			Cattle Egret	*Bubulcus ibis*	LC	0.91	R	Carnivores
91			Little Egret	*Egretta garzetta*	LC	1.37	R	Carnivores
92		Threskiornithidae	Red-naped Ibis	*Pseudibis papillosa*	LC	0.61	WV	Omnivores
93	Piciformes	Picidae	Lesser-goldenbacked Woodpecker	*Dinopium benghalensis*	LC	1.98	R	Insectivores
94		Megalaimidae	Brown-headed Barbet	*Psilopogon zeylanicus*	LC	0.30	R	Omnivores
95	Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	LC	0.91	R	Insectivores
96	Psittaciformes	Psittaculidae	Plum-headed Parakeet	*Psittacula cyanocephala*	LC	0.15	R	Frugivores
97			Alexandrine Parakeet	*Psittacula eupatria*	NT	1.98	R	Frugivores
98			Rose-ringed Parakeet	*Psittacula krameri*	LC	2.28	R	Frugivores
99	Strigiformes	Strigidae	Jungle Owlet	*Glaucidium radiatum*	LC	0.46	R	Carnivores

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