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Bird Diversity on an Under-Construction Educational Campus: A Case Study of Nalanda University, Rajgir, India

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ABSTRACT

Bird species have been critically impacted by increasing anthropogenic activities such as infrastructural construction. Academic institutions with dedicated semi-natural landscapes may provide shelter to high bird diversity. However, assessing the bird diversity of an under-construction campus becomes critical for future comparison. This study was conducted at Nalanda University Campus, India, for five months, as the campus was at the fag-end of the construction phase with diverse land use changes. Ninety-one bird species were found on campus primarily dominated by insectivores and omnivores. Occurrence, and migratory status of the species revealed that 47% were resident, primarily occupying aquatic habitats. Despite presence of Least Concern IUCN status bird species in the campus, substantial number of them had a declining abundance index at the national level. Sites with high land conversion showed a low number of bird species. The overall dominance and evenness highlighted a good bird diversity, contrary to altered sites where both these attributes were high. Data for the documented bird species on citizen science platforms highlighted limited information on species interactions. This study attempted to bring attention to the unchecked impact of construction activities on bird diversity and regular monitoring in the widely discussed emerging semi-natural shelters, i.e., academic campuses.

Key words: Avifauna, India, Academic campus, Bird diversity, Bird counting, Citizen science

INTRODUCTION

The increasing human population and its intense use of natural resources have long been detrimental factors behind habitat fragmentation and land use changes directly impacting biodiversity (Pereira et al. 2012). The demand for land to establish settlements and orthodox agricultural practices, along with resource extraction, led to a 13 to 75% reduction in the global biodiversity (Wintle et al. 2019) with increasing land conversion. The long-standing notion is that large fragments harbour high biodiversity, sometimes undervaluing the small patches as a reserve or refuge for local biodiversity. Increasing urban areas or human-dominated landscapes is creating novel habitats in the form of urban green spaces (Iwachido et al. 2023). Though, urbanisation has considerable implications on a large scale, pockets of urban green spaces have the potential to support native as well as threatened species (Guthula et al. 2022). These novel habitats in human-dominated landscapes have various forms, such as urban parks, plantation sites, streetscapes, and institutional areas (Jim and Chen 2003, Liu et al. 2017).

A recent study found that 10% of vascular plant species were present in only 0.0008% of the academic campus in China (Liu et al. 2017). Similar patterns were also reported in some of the academic institutions of India where high plant (Rajendran et al. 2014) and bird species richness was recorded (Devi et al. 2012). However, management or development activities at an academic institution often ignore the available biodiversity, which is especially aggravated when a new institution is being set up and the natural green space is heavily transformed without accounting for the existing species diversity. It can be detrimental to species diversity, their interactions, and the ecosystem services they provide, leading to the collapse of ecosystem functioning (Bregman et al. 2015).

As a prominent and recognisable taxon, birds have served as valuable indicators for assessing the health of ecosystems, biodiversity richness, and the impacts of climate variations (Warren et al. 2012). With an estimated global count of around 9700 bird species,

India contributes significantly with approximately 1358 species and subspecies, including 26 uncommon or accidental species and 42 endemic species (Callaghan et al. 2021, Anonymous 2023a, Grimmett et al. 2011). Human-dominated landscapes have become home to various avian species, underscoring the importance of understanding their ecology within such settings to ensure their sustained well-being and the ecological balance of urban ecosystems. Furthermore, citizen science (CS) platforms have provided the accessibility to contribute data for a better understanding of species as well as ecosystems (Diaz et al. 2024). These platforms are a resource hub for understudied regions lacking information on species and their interactions. However, it cannot be neglected that diversity and robustness in the data are also a critical factor where most CS platforms, such as (iNaturalist, eBird) constitute sporadic information and primarily have data related to species identification and geolocation. This might serve a limited purpose in understanding the ecology of species interactions.

In recent years, increased attention has been directed towards urban bird conservation, identifying suitable habitats, and managing them to support diverse bird populations (Hedblom et al. 2017). Among these habitats, academic campuses stand out due to their combination of diverse land cover, which acts as a suitable reserve for resident and migratory bird species. Birds, being mobile and highly responsive to environmental changes, serve as reliable indicators of biological diversity and ecosystem health (Mekonen 2017).

Therefore, we investigated the biodiversity potential of an under-constructed (under-developed) academic campus using birds as a representative group. We studied the campus bird species richness across the terrestrial and aquatic habitat. Furthermore, we explored secondary data to get information on feeding habits, bird's national abundance index, IUCN red list status, and their feeding records on the two biggest CS platforms, iNaturalist (Anonymous 2023b) and Macaulay Library (ebird) (Anonymous 2024b).

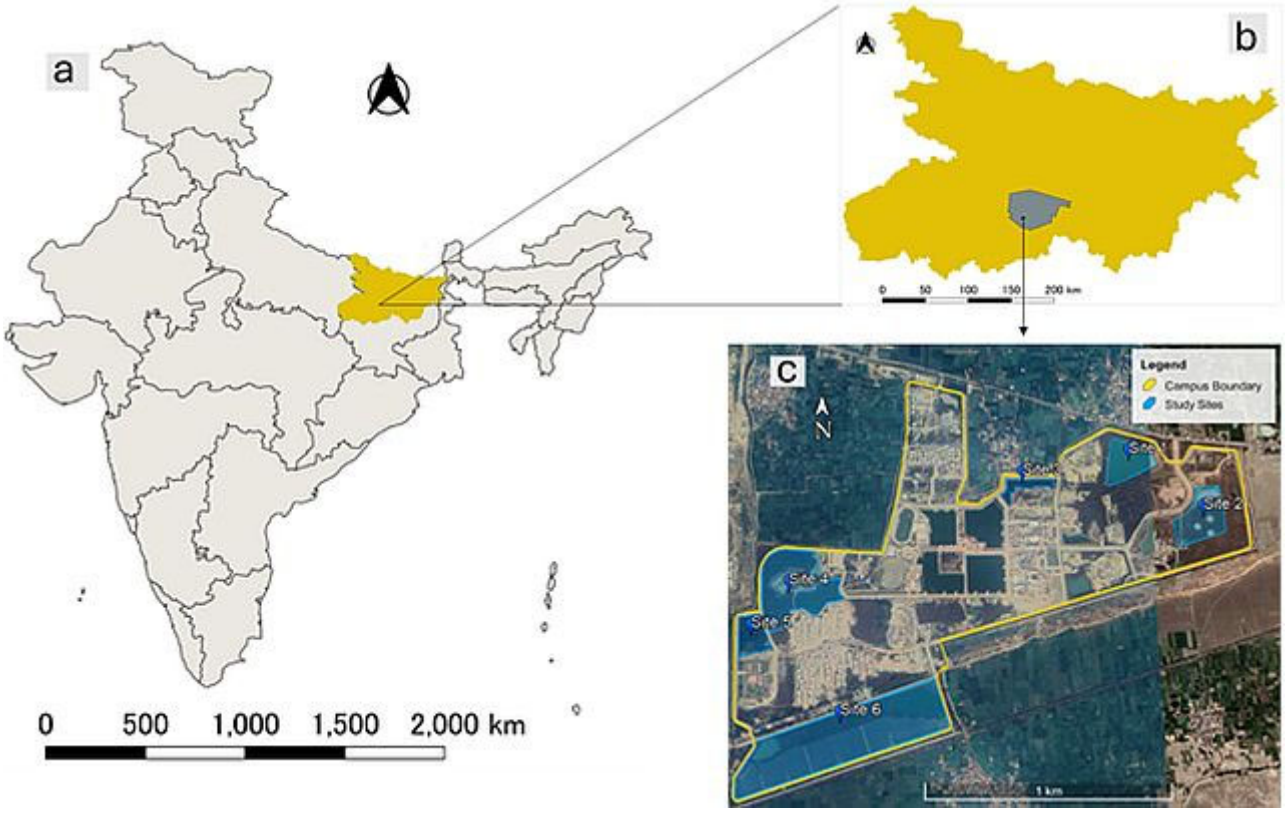

Figure 1. State of Bihar highlighted on India's map (a), Nalanda district in the Bihar state of India (b), and the study sites marked with blue colour within the campus boundary in the Nalanda district of Bihar (c)

Through this paper, we aim to recognise the diligent consideration needed during the development of academic campuses, which can serve as long-term biodiversity reserves and the need for more diverse and detailed data on CS platforms. We tried to answer the following questions: 1) How many bird species were present on an under-construction academic campus of Nalanda University? 2) What was their feeding habit, national abundance index, and IUCN red list status? 3) How well were those species represented on the CS platforms in the studied region? 4) How detailed were the information or records on CS platforms for those campus-observed bird species?

METHODS

The present study was conducted within an under-constructed Nalanda University (NU) campus (25°0'30.76" N and 25°1'37.14" N and 85°21'58.28" E and 85°23'16.8'' E) situated in the Rajgir town of Nalanda district, Bihar, India (Fig. 1). It has an area of 455 acres (out of which 100 acres dedicated to water bodies, 300 acres to green landscapes and 55 acres for buildings) at an elevation of 68 m above sea level. The campus has various land-use forms such as built-up areas (buildings, paved roads), artificial ponds, marshes, small patchy grassy landscapes, or open natural ecosystems (ONEs), tree groves/ plantation sites and open sports grounds. The monthly minimum and maximum temperature of the coldest and warmest months ranges from 9.6 to 40.2°C. The mean annual temperature is 26.3°C, and the mean annual precipitation is 971 mm (Fleri et al. 2021).

The site was selected because of two main characteristics: (1) it is situated in one of the data deficit regions in India in terms of biodiversity. Despite Bihar's abundance of wetlands, there is a paucity of studies focussing on avifaunal diversity in the state, with only a few studies shedding light on the bird populations of Rajgir Wildlife Sanctuary, a natural conservation area (Mehta and sharma 2022, Kumar and Prabhat 2013, Manjula et al. 2022) and only one campus-based study in Bihar State (Kumari et al. 2021). (2) Nalanda University has been known for its unique approach towards net-zero campus construction by amalgamating modern techniques and ancient architecture (Anonymous 2024c). In this regard, this campus provides an ideal setting to answer our questions and reveal its potential as a safe reserve for birds.

This study was conducted for five months, from August to December 2022. We selected six sites withing the campus for bird observation depending on its terrestrial or aquatic nature. Three of them were terrestrial or non-aquatic ('site 2', 'site 5' and 'site 6') and other three were dominated by aquatic habitat ('site 1', 'site 3' and 'site 4'). We used the point count method to document bird species because of its efficiency in estimating the species diversity and abundance in changing environments (Urfi et al. 2005, Ralph et al. 1995). As mentioned earlier, the campus has been undergoing extensive construction, frequently necessitating the transportation of huge vehicles, storing raw materials, and excavating sites for new buildings, resulting in a constantly changing landscape. The survey was conducted on days with clear weather between 15:30 and 18:30 hrs, three to four times a week.

During the investigation, the bird's presence and feeding patterns, such as insectivores, frugivores, granivores, piscivores, nectarivores, carnivores, and omnivores, were documented (secondary data was explored for species whose feeding habit was not observed during survey). We used 10×50 Celestron binoculars, Cuddle Back Digital Flash Black camera trap and a Nikon P550 point-and-shoot camera for the survey. Bird species were identified by referring to bird's guidebook (Grimmett et al. 2011) and for sound identification, xeno-canto database was referred (Anonymous 2023d). The E-bird mobile app was used to count and record the number of bird species and their taxonomic information. Birds that were nearly always seen during field trips and bred in that area were classified as residents (R), local migrants (LM), which were frequently seen during field trips but bred elsewhere, and winter migrants (WM), who were not native to the region. Only species whose identification was confirmed were added to the final checklist. Furthermore, IUCN data was explored to document their threat status (Anonymous 2023c). We also explored 'State of Indian Birds' database (Anonymous 2023a) and birdlife data zone (Anonymous 2024d) to get information on the habitat preferences (Forest,

Wetland, Grassland, Shrubland, Built-up, Scrubland, Open Natural Ecosystems, Hills, Cropland, Plantation) and national abundance index of these species.

We further explored the CS platforms, i.e., iNatuarlist and Macaulay Library, to determine the number of observations recorded for documented bird species in Bihar state. We selected these two platforms as they are one of the most prominent media (images) repositories for birds. Every bird species was searched on the platforms to record the number of verified observations. Only research grade (for iNaturalist) and confirmed observations (for Macaulay Library) were considered. To examine the quality of usage of CS data in studies other than species identification and diversity in the data, here media (images), we looked at the feeding records for the concerned species in the uploaded media. Using the eBird platform, we also assessed the bird species observed at the NU campus for their overall frequency of observation in the whole Nalanda district and Bihar state.

We performed descriptive analysis to estimate the species at each site based on their movement patterns and feeding behaviour. We also estimated the frequency for the bird species at the campus based on surveyed sites and performed a Spearman correlation test to find out how strongly they are correlated with the frequency of the same birds in the Nalanda district and Bihar state. We further used the tabula package's 'heterogeneity' (dominance) and 'evenness' functions (Frerebeau 2023) to determine which species and site had the dominance and evenness characteristics. Based on the preferred habitat data from the secondary sources, we used the UpSetR package (Conway et al. 2017) to examine the number of bird species preferring more than one potential habitat. Furthermore, we visualised the bird's interaction with different feeding materials using the *Flourish* studio (Anonymous 2024a). All the analyses were performed using the R software (version 4.3.2).

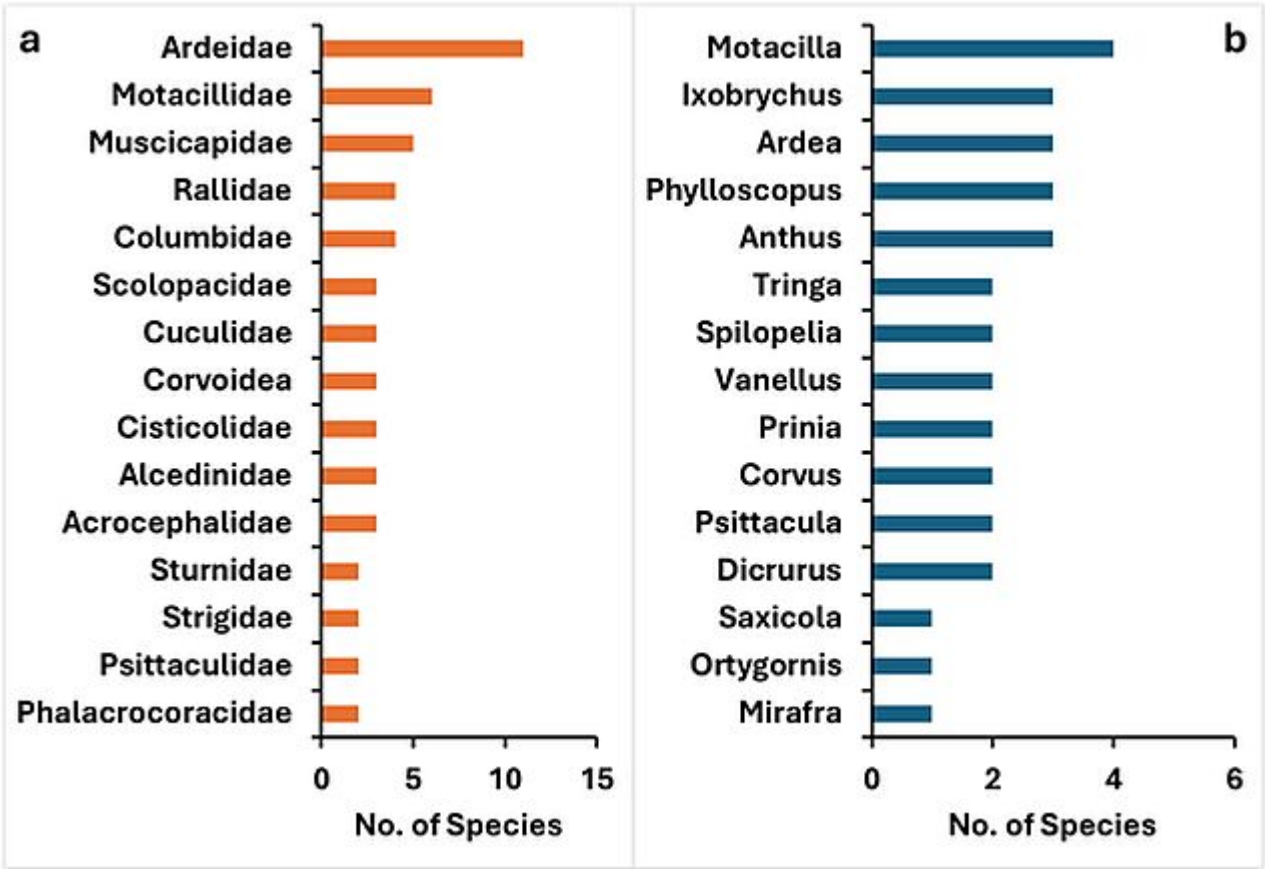

Figure 2. Top 15 families (a) and genera (b) of documented bird species on NU campus

RESULTS

Ninety-one species of birds belonging to 21 orders and 42 families, and 73 genera were documented on campus. The family Ardeidae (n = 11) had the highest number of species, followed by Motacillidae (n = 8) and Muscicapidae (n = 5). In addition, *Motacilla* (n = 4) was the dominant genera, followed by *Anthus, Ardea, Ixobrychus*, and *Phylloscopus*, with three species each (Fig. 2). Out of 91 species, a total of 13 species had sightings in the range of 3 - 9% of total sightings. In addition, 11 species had 1 - 2% of total sightings. On the other hand, more than half of bird species had <1% of total sightings on campus. Bird species preferred aquatic habitats, where 71 species were spotted in the sites constituting ponds, whereas 60 species were spotted on other than aquatic habitats. However, 55 species were shared between aquatic and non-aquatic habitats. *Acridotheres tristis* (Common myna) and *Dicrurus macrocercus* (Black drongo) were the commonly found birds present in all the survey sites. Out of the bird species found only in aquatic survey sites, *Motacilla maderaspatensis* (White-browed Wagtail) and *Cypsiurus balasiensis* (Asian palm swift) were the commonly seen bird species. Twelve of the bird species seen present only in aquatic habitats were recorded only in one of the survey sites. On the contrary, *Anastomus oscitans* (Asian openbill) was the commonly found bird species in the terrestrial or non-aquatic sites. Seven bird species were seen only in one of the non-aquatic sites.

Aquatic habitats such as 'site 1' (39 spp), 'site 3' (45 spp) and 'site 4' (45 spp) comprised of the greatest number of bird species. On the other hand, terrestrial habitats such as 'site 2' (30 spp), 'site 5' (44 spp) and 'site 6' (20 spp) comparatively comprised less species. It was seen that the sites constituting aquatic habitats prominently harboured more resident bird species. Based on the movement patterns, it was revealed that 47% (n = 43) of the bird species were residents, followed by local migrants 17% (n = 16). 'Site 4' and 'site 5' had the greatest number of resident species (n = 27). On the contrary, 'site 6' had the lowest resident bird species (n = 19). Insectivores, with 27% (n = 24) and omnivores, with 23% (n = 21), were the dominant feeding behaviours of the species on the campus. It was closely followed by carnivores with 20% (n = 18). 'Site 4' as an aquatic habitat had the greatest number of insectivores bird species (n = 10) followed by 'site 3' (n = 9) (Fig. 3). The heterogeneity and

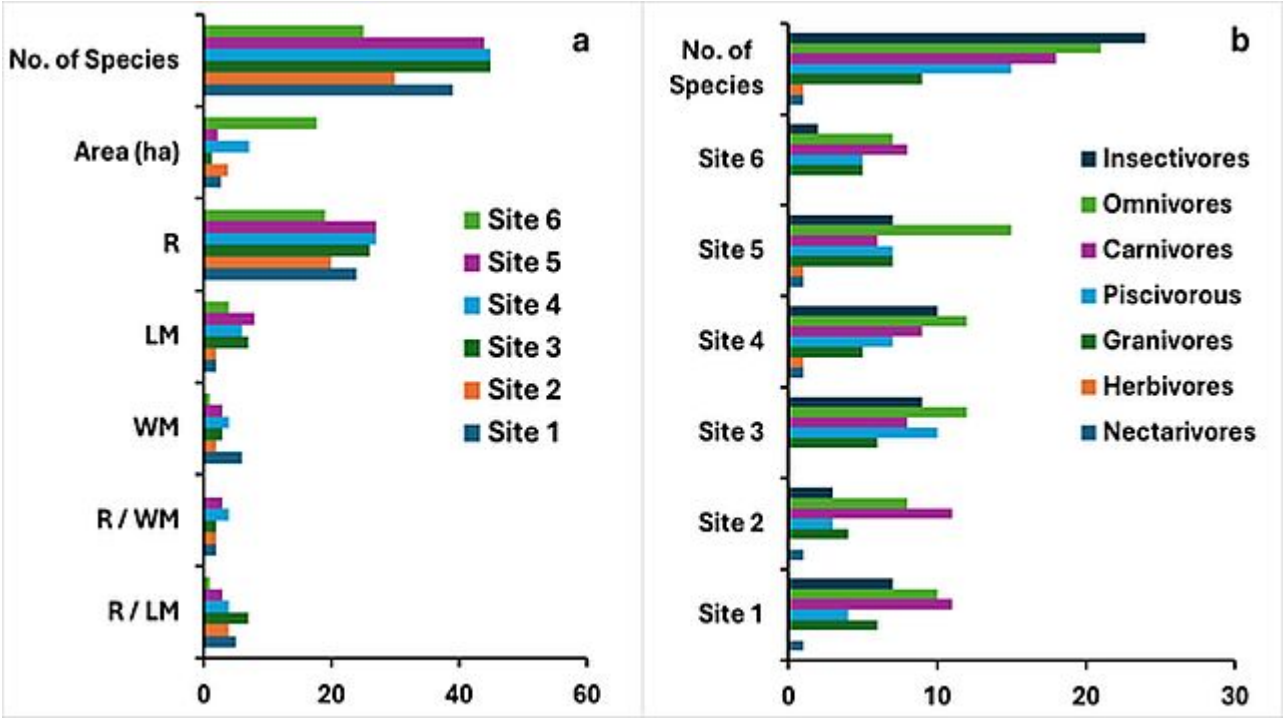

Figure 3. Number of species based on movement patterns (a) and feeding behaviour (b) across the study sites. On the y axis in figure (a) Residents (R), Local Migrant (LM), Winter Migrant (WM)

evenness assessment highlighted that 'Site 2' (d = 0.083, e = 0.40) and 'Site 6' (d = 0.081, e = 0.48) had the highest dominance and evenness.

Most observed bird species (97%, n = 89) were of IUCN Least Concern (LC). There were two near-threatened (NT) species, i.e., Alexandrine Parakeet (*Psittacula krameri)* and Painted stork (*Mycteria leucocephala*). Like the IUCN red list pattern, most species showed a stable (47%, n = 43) abundance index at the national level. Contrastingly, 25% (n = 22) LC bird species along with one NT species, i.e., *Mycteria leucocephala* had declining abundance index at the national level. Using the secondary data on general habitat preferences, it was found that wetland was the most suitable habitat. The assessment of similarity among the habitat preferences showed that patchy grassy landscape or Open Natural Ecosystems (ONEs) (n = 10) was the second most favoured habitat by the bird species. In addition, nine species preferred forest areas (tree groves/plantation sites). Habitats, such as grassland, shrubland, and cropland, were some of the other suitable habitats preferred by those birds. Contrastingly, built-up areas were also preferred by a substantial number of bird species found in natural habitats (Fig. 4).

The average frequency of bird species in the campus was 45%, with most being resident birds. In addition, 25 bird species occupied more than 50% of the campus. The average frequency of documented bird species at the district level was 12.67%, and 10.67% at the state level. Comparing the top 25 bird species (average frequency was 88%) of the campus with the district (24.4%) and state (19.19%) level inventory revealed a low rate at both levels of the administrative boundary. There was a positive correlation seen between the campus birds and their presence in the district ($r = 0.56$, $p < 0.001$) and state ($r = 0.51$, $p < 0.001$). However, a significant correlation was seen between district and state presence of the campus bird species ($r = 0.89$, $p = 0.01$) (Fig. 5). Regarding species, *Motacilla maderaspatensis* (d = 1, e = 1) had a high influence on the dominance index of the campus. Most species influencing the dominance were migrant status (n = 17). In addition, 17 out of 19 bird species with low dominance index were of resident status, whereas most of these species have a preference for tree

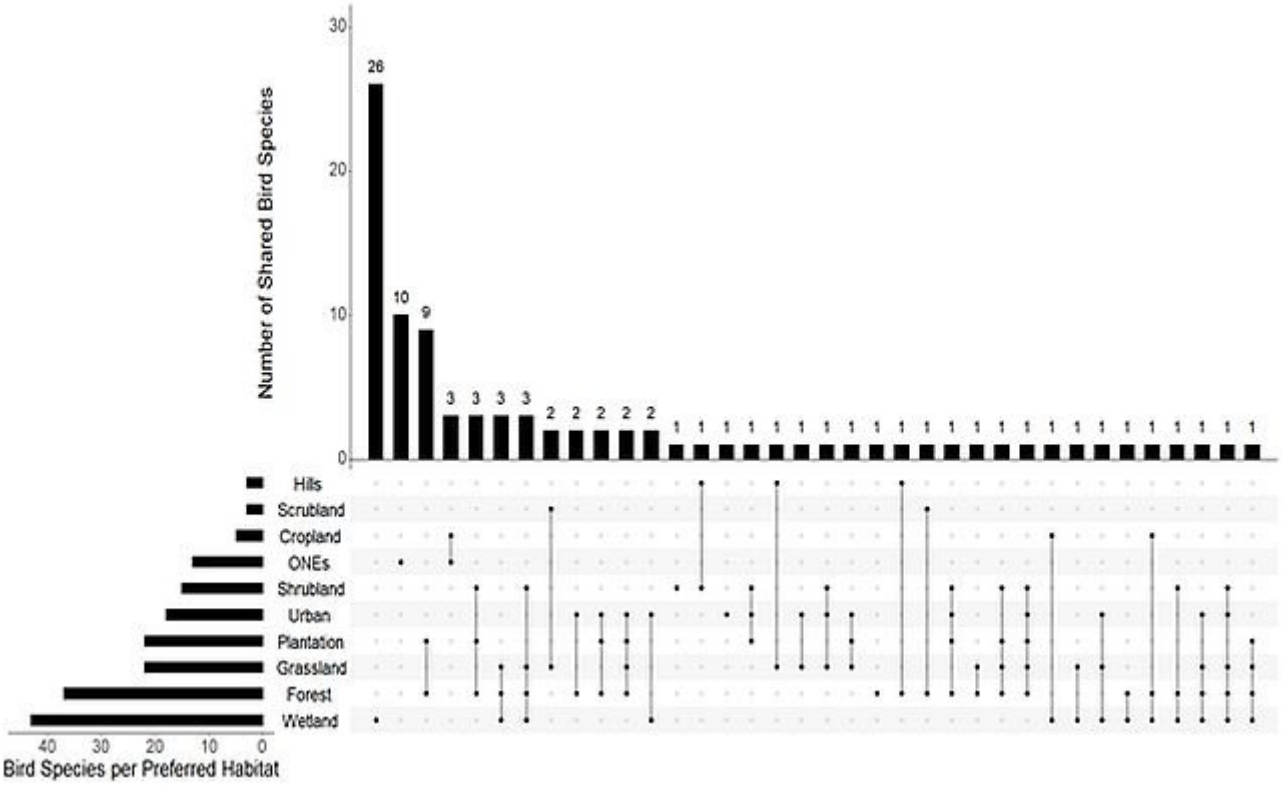

Figure 4. Number of bird species based on the preferred habitats (bars). The dotted lines below the bars show the number of bird species preferring their respective habitats

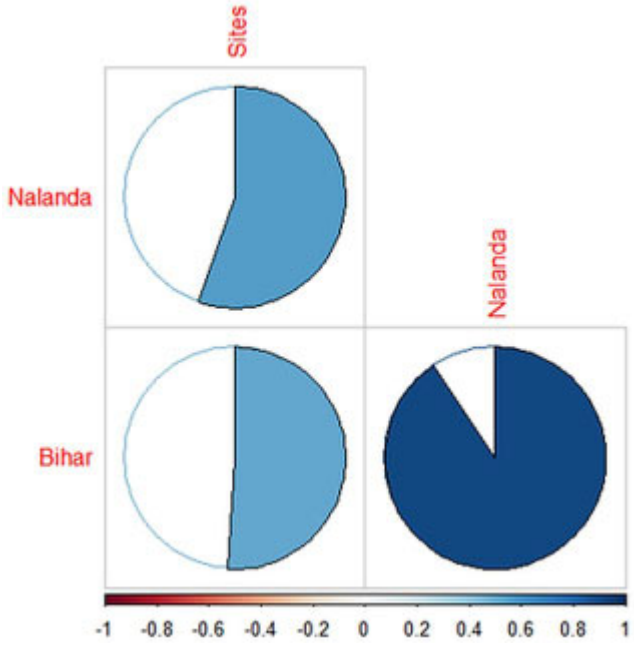

Figure 5. Correlation matrices of campus birds with district (Nalanda) and state (Bihar) level bird diversity

groves (n = 9) and aquatic (n = 9) habitats.

Our attempt to investigate the CS platforms unveiled that out of 91 bird species on the campus, ebird (92%, n = 84) had a better species representation than iNatuarlist (79%, n = 72). Concerning observations, ebird comprised 1109 observations, whereas iNatuarlist had 586 observations. The top bird species with more than 20 observations on ebird were prominently omnivores (n = 8), whereas 50% of the species with more than 20 observations on iNatuarlist were omnivores (n = 4). The number of species with feeding records substantially differed on both platforms, where 18 bird species had feeding observations on ebird but only seven on iNaturalist. Similarly, the number of unique feeding records was more than three-fold on ebird (n = 22) compared to iNaturalist (n = 7). Out of the seven feeding records on the iNaturalist, only three were identified at taxonomic level. On the other hand, out of 16 feeding material categories on ebird, 15 could be identified as flora or fauna. However, out of all the feeding records on both the platforms, only one was identified at the species level, i.e., *Melaleuca viminalis* consumed by *Cinnyris asiaticus* and two feeding records at the genus level, i.e., *Ixora* sp and *Coccinia* sp consumed by *Cinnyris asiaticus* and *Gracupica contra,* respectively (Fig. 6).

DISCUSSION

The under constructed campus birds constituting a large number of species is a significant reiteration of the previous arguments that academic campuses have been biodiversity reserves for species (Liu et al. 2017). It is 45% (91/204) of the proportion of species recorded at the district level. Many aquatic and terrestrial species are present on the campus, constituting 23.63% (91/385) of the state's bird species, highlighting the campus's significance as a natural reserve. For example, 29% of China's bird species were reported on 38 academic campuses (Zhang et al. 2018), and 58.7% of India's bird species were reported from 0.0088% of India's land area occupied by academic campuses (Guthula et al. 2022).

The sites with aquatic habitat harboured a greater number of species compared to non-aquatic habitats evidently highlighted its importance especially for resident birds. At the studied campus, artificial ponds, and dense patches of perennial tall grass (*Saccharum spontaneum*) have a heterogenous characteristics providing ample shade and resources for insectivorous birds. Anderle et al. (2023) also highlighted that habitat heterogeneity promotes diversity even in agricultural landscapes. It was also seen in the study that the area (size) of sites was not the main factor behind the number of species but the maintenance of the heterogeneity of site. For example, 'Site 6' is a solar park with a honogenous habitat and considerably the highest proportion of campus land allocation (20 acres); however, it is one of the less occupied/utilized habitats by birds, possibly because it may leave less space for resident birds having specific habitat preferences to that site. In addition, areas such as 'site 2' where substantial land conversion took place by creating helipads had a low number of bird species.

The dominant feeding habit was insectivorous, signifying the presence and need for ample arthropod diversity. However, studies have shown that land conversion has significantly impacted one of the most prominent faunal groups, i.e., invertebrates (McIntyre et al. 2001). The second most prevalent

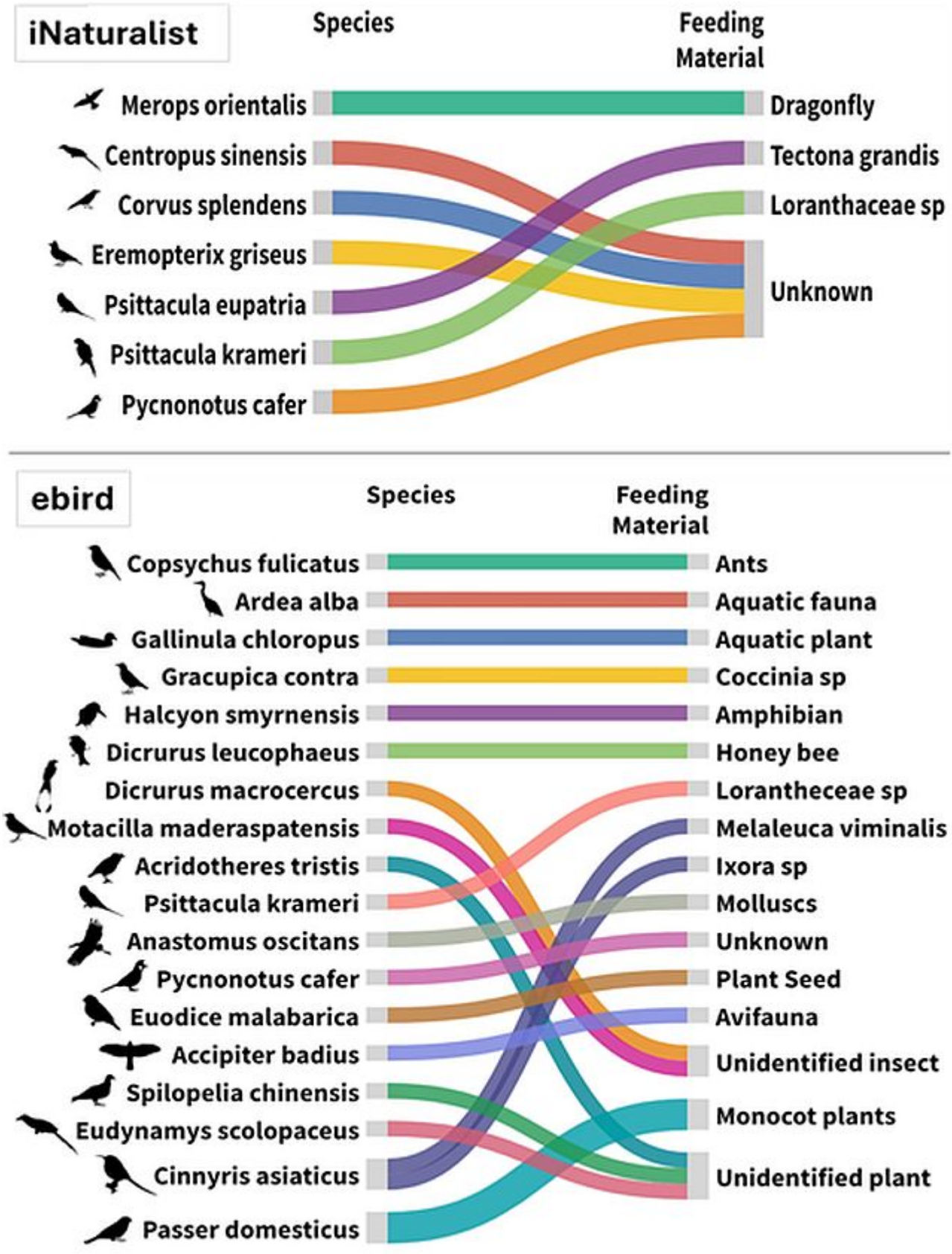

Figure 6. Different types of feeding materials documented for the bird species from the media data on the two dominant CS platforms. Birds illustrations were added using *Phylopic* (Keesey 2024)

feed habit was omnivorous pointing out at the dependency of birds on the available vegetation. Contrary to the LC status of most bird species, their declining abundance index at the national level brings our focus beyond the global threat data due to their probability of being outdated (Rondinini et al. 2014). The two NT species, with one having a declining national abundance index, favour water bodies as the habitat, and its feeding habit of being piscivorous accounts for a suitable prey population. However, soil sealing or concrete bottom layering of the water bodies on the campus may diminish their potential to sustain a healthy prey-predator interaction (Oertli et al. 2023) in the longer run and negatively impact the biodiversity. Furthermore, pond depth and the water recharging process of the ponds are other critical factors in sustaining aquatic biodiversity, including that of waterbirds. This study revealed two bird species (*Bubulcus ibis* and *Anthus similis*) that have never been recorded on any digital platform from this region. Even of these two species, *Anthus similis* had never been documented in any bird surveys from the entire Bihar state.

The similarities in the habitat preferences of the documented bird species are critical to consider when planning infrastructural development activities. Despite many bird species favouring aquatic or ONEs habitats, >50% of them also prefer more than one habitat, which calls for maintaining habitat heterogeneity to make university campuses the preferred habitat for bird diversity. It also supports bird species in maintaining stable populations by protecting themselves from exposure to predators. For example, the rocky landscapes and tall grassy patches protect the laid eggs of lapwings and Night Jars from flying predators. The overall low dominance and evenness index for the sites showed good bird diversity on the campus. However, sites with substantial land conversion comprised the highest dominance index. It reiterated the need for biodiversity assessments to track its status before, during and after the infrastructural development activities. In addition, the campus serving as a natural reserve was seen during the dry weather season (beyond the study period) when heat waves posed a high risk of forest fires in nearby hills. The fire season also witnesses the drying up of natural water bodies due to rising temperatures up to 42°C. The birds, which were hardly spotted on the campus on a regular basis, started appearing in large numbers during fire incidence in nearby forested landscapes like Grey Wagtail (*Motacilla cinerea*), Painted Snipes (*Rostratula benghalensis*), Intermediate Egrets (*Ardea intermedia*), Bee-eaters (*Merops* spp.), Flycatchers (Muscicapidae family), Brown Rock Chats (*Oenanthe fusca*), and Grey Herons (*Ardea cinerea*). Their sightings are concentrated around ponds inside the campus, giving a very positive sign in critical times. The campus turned as a shock absorber for avifauna and provides water and food during unfavourable times.

CS platforms can act as providers of big data, which was seen in our study where a large number of observations for the documented bird species were available on the two CS platforms for the state of Bihar. However, they lacked descriptive information such as ecosystem type or species interactions. Additionally, there were very limited records for the bird feeding habits on these platforms, nonetheless ebird platform comprised more feeding records than iNaturalist that could be taxonomically identified. It highlighted the need for formal inculcating of CS knowledge to the users and how to report good quality data (Kosmala et al. 2016).

The study had limitations, such as estimating the weight of construction to find a relationship with the bird diversity, which was not considered due to time constraint and comparatively long-term construction activities where their impact may not be visible during the study period. Furthermore, we did not undertake the vegetation survey in this study due to limited resources and limitations in moving within the survey sites due to construction activities. This short-term study could have missed the seasonal variation in campus bird diversity failing to reveal the spectrum of non-resident and migratory birds. In addition, the study was not carried out during night to document the nocturnal species. However, we did observe some of them in the evening time. Nevertheless, this study aimed to document bird species, which could motivate future bird counting after construction and examine how bird diversity patterns change on an under-construction to fully constructed functional campus.

It has been pointed out that many bird species are sustained by big habitat patches (Mayorga et al.

2020), whereas bird species richness substantially increases with the increase in campus area (Guthula et al. 2022). However, data on campus bird diversity must be curated to support this argument. Availability of quality bird inventory of academic campuses in India, especially from data deficit regions (such as Bihar, where only one campus bird inventory was available other than this study) can probably provide more insights into the bird diversity patterns (Guthula et al. 2022) along with ecosystem functioning information.

Our study suggested and supported that high biodiversity could be sustained in the human-dominated landscape, highlighting the concept of reconciliation ecology (Rosenzweig, 2003). University campuses turned out to be intact fragments and open labs of nature regarding biodiversity conservation potential. Birds can act under the meta-population framework by exploiting diverse habitat fragments; however, they must be maintained within the campus for resident species. Unchecked disruptions caused during the development processes on the campus not only remove the old vegetation but also promote non-native species to establish. With rapid urbanisation, establishing urban conservation sites is becoming limited; thus, prioritizing biodiversity conservation sites in the campus development from the initial planning stage with continuous monitoring could bring it into the purview of OECMs (other effective area-based conservation measures). It will give due attention to conservation practices within the campus with a global perspective and prove beneficial for conserving high biodiversity in small land areas.

CONCLUSIONS

The high bird diversity on an under constructed campus of Nalanda University signifies its potential as a suitable landscape for biodiversity reserves. The campus has 45% of the species recorded from the Nalanda district consisting of many aquatic and terrestrial species and accounts for 23.63% of the bird species reported from Bihar. Our study concluded that the area (size) of sites was not the main factor behind the number of species but the heterogeneity of area. The area is dominated by insectivores and alteration of the landscape will impact the food chain in the area and thus the diversity of the species will get affected in future.

Authors' contributions: SSP and SP conceived the study; SP conducted the field survey and collected the initial data; HY collected additional data, performed formal analysis and visualization, and wrote the original draft and HY, SP, and SSP reviewed, revised, and edited the manuscript, and approved the submitted version.

Conflict of interest: Authors declare no conflict of interest.

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