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COMMUNICATION

Avian diversity in a fragmented landscape of central Indian forests (Bhopal Forest Circle)

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Abstract: With increasing fragmentation of natural areas and a dramatic reduction of forest cover in several parts of the world, quantifying the impact of such changes on species richness and community dynamics has been a subject of much concern. Therefore, this study intends to assess avifaunal biodiversity in fragmented forests. Forest patches between the sizes of 10ha and 700ha were identified in Bhopal Forest Circle (BFC), which covers the Vindhyan plateau. Forest patches were classified based on their size and degree of isolation. A sample of 21 forest fragments was selected using proportional sampling. Bird surveys were conducted using the point count method at each site. Three replicates were taken at each site. Avian species richness of each patch was calculated. The results suggest that species richness is positively associated with the size of the forest patches. Larger forest patches such as Binapur (166ha, Chao 1= 73), Sayar (107ha, Chao 1= 78) and Kalyanpura (133ha, Chao 1= 80) had relatively high species richness, except for patches including Narsinghgarh (393ha, Chao 1= 28) and Singota (184ha, Chao 1= 45) with high levels of anthropogenic disturbance. Smaller forest patches were found to have fewer bird species, although small forest patches with lesser degrees of anthropogenic disturbance such as Lalghati (99ha, Chao 1 = 62), Lasudli (16ha, Chao 1 = 65), Ghot (36ha, Chao 1 = 53), and Nasipur (23ha, Chao 1 =52) were more diverse than other patches. These patches were more protected due to being sacred groves (Lalghati and Lasudli) or under private ownership (Ghot and Nasipur). A total of 131 bird species were recorded from all the sampled forest patches. These results suggest that forest patches embedded in an agrarian landscape play a vital role in conserving biodiversity, hence conservation efforts should also be focused on these forest fragments.

Keywords: Avian diversity, BFC, degree of isolation, Forest patches, patch size.

Hindi संक्षेप: प्राकृतिक क्षेत्रों के बढ़ते विखंडन और विश्व के अनेक भागों के वन क्षेत्रो में हो रही कमी के साथ प्रजातियों की समृद्धि और सामुदायिक गतिशीलता पर पड़ने वाले परिवर्तनों के प्रभाव की मात्रा का आकलन करना बहुत चिंता का विषय रहा है । अतः, यह अध्ययन खंडित वनों में पक्षी विविधता का आकलन करने के लिए किया गया है। 10ha और 700ha के आकार के बीच के वन खंड, भोपाल वन वृत्त (BFC) में पहचाने गए, जो विंध्य पठार का भाग है । इन वन खंडो को उनके आकार (size) और अलगाव के स्तरो (degree of Isolation) के आधार पर वर्गीकृत किया गया । आनुपातिक नमूना चयन (proportional sampling) का उपयोग करते हुए 21 वन खंडो का नमूना चुना गया । प्वाइंट काउंट (point count) विधि का उपयोग कर के प्रत्येक वन खंड में पक्षी निरिक्षण किया गया और 3 पुनरावृति की गई। प्रत्येक खंड की पक्षी प्रजातियों की समृद्धि की गणना की गई थी। परिणाम दर्शाते हैं कि पक्षी प्रजातियों की संख्या सकारात्मक रूप से वन खंडो के आकार से जुड़ी हुई है। बीनापुर (166ha, Chao 1= 73), सायर (107ha,Chao1=78) और कल्याणपुरा (133ha, Chao 1=80) जैसे बड़े वन खंडो में अपेक्षाकृत अधिक प्रजातियों की संख्या थी। नरसिंहगढ़ (393ha, chao 1=28) और सिंगोटा (184ha, Chao 1 =45) खंडो में पक्षी प्रजातियों की संख्या कम मिली क्योंकि इन खंडो में मानवजनित गतिविधियों का उच्च स्तर पाया गया । छोटे वन खंडो में पक्षी प्रजातियों की संख्या कम पाई गई । यद्यपि लालघाटी (99ha, chao 1 = 62), लासुडली (16ha, chao 1 = 65), घोट (36ha, chao 1 = 53), और नसीपुर (23ha, chao 1 = 52) जैसे खंडो में मानवजनित गतिविधियां कम पाई गई। अतः इन वन खंडो के छोटे होने के बाद भी अन्य वन खंडो की तुलना में पक्षी विविधता अधिक पाई गई । ये वन खंड पवित्र स्थल (लालघाटी और लासूडली) या निजी स्वामित्व (घोट और नसीपुर) के अंतर्गत होने के कारण अधिक संरक्षित थे। सभी नमूना वन खंडो से कुल 131 पक्षी प्रजातियाँ दर्ज की गईं। इन परिणामों से पता चलता है कि कृषि परिदृश्य में लगे वन खंड जैव विविधता के संरक्षण में महत्वपूर्ण भूमिका निभाते हैं, इसलिए इन वन खण्डों में संरक्षण प्रयासों पर भी ध्यान दिया जाना चाहिए।

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INTRODUCTION

Habitat destruction is taking place at an alarming rate in various parts of the world. Land-use and land cover change are major causes of biodiversity loss. Vast continuous tropical forests have been transformed into remnant forests scattered across human-dominated areas in the last few decades due to growth in populations and changes in technology (Wiens 1995; Hill et al. 2011). This conversion of continuous forests into many smaller forest patches leads to physical and biological changes in the forest environment, which lead to changes in habitat structure, and subsequently to biodiversity loss. These physical and biological changes are reduced patch size, increased degree of isolation and increase in new habitat types; however, overall suitable habitat decreases with habitat fragmentation resulting in loss of species diversity (Andren 1994). The fragmentation of the patches also leads to more significant exposure to human land uses along fragment edges commencing persistent changes to the ecological structure and function of the remaining fragments leading to loss of biodiversity (Shahabuddin & Terborgh 1999; Feeley et al. 2007). Forest patches resulted from the change in land use and land cover can be defined as relatively homogenous areas which differ from its surrounding land use within the landscape (Peters et al. 2009). Recent studies indicate that the fragmentation has impacts on biotic interactions between species (Morris 2010) and if not focused can lead to a cascade effect in the tropical ecosystem, rising concerns on viability of these patches in long-term conservation (Hill et al. 2011). Forest remnants or patches need attention due to an increase in their number as a result of the intensification of agriculture and deforestation. These patches can play a vital role in conserving the biodiversity and overall health of the ecosystem in a landscape. There is a lack of information on the biodiversity of forests patches in human-modified landscapes, especially in rural areas. Conservation studies have focused on areas with a high diversity of flora and fauna, i.e., protected areas. But forest patches demarcated as reserve forests, situated in rural landscapes are deprived of attention from conservationists (Chazdon et al. 2009). These patches can play a vital role in providing refuge to important species and act as a stepping stone in corridor development. The forest patches in these landscapes are of different size, shape, degree of isolation, and degree of disturbance. Together, these patches can support a variety of flora and fauna and save important species from local extinction. Therefore, there should be studies based on integrated landscape conservation approach in these fragmented landscapes. These studies should be focused on population, their dispersal, habitat use, the effect of context, connectivity and degree of disturbance on the population of local flora and fauna (Chazdon et al. 2009). There have been various studies across the world in which community structure and composition of vegetation and animals were examined. Many of them also investigated the effect of patch level as well as landscape levels variables on the composition and configuration of the flora and fauna of the forest patches. There are also studies where community dynamics were examined in forest patches.

Oliver et al. (2011), in their study in urban parks found that park area was the best predictor of species richness of resident birds and for migratory species, the best predictors were habitat diversity and developed area within the park. In another study conducted to study the influence of regional gradients in land-use on richness, composition and turnover of bird assemblages in small forests, it was again concluded that patch area is one of the most important variables at patch level which affects the richness of the bird communities (Bennett et al. 2004). Similarly, a study conducted in urbanized tropical islands it was concluded that patch size has the highest predictive power in explaining the species richness of the resident birds of the forest patches (Suarez-Rubio & Thomlinson 2009). A study on relative effects of fragment size and connectivity on bird communities in Atlantic rain forests suggest that only terrestrial insectivores, omnivores and frugivorous birds were affected by patch area. Other feeding guilds such as understory insectivores, nectarivorous, and others were not affected by the area of the patch (Martensen et al. 2008).

There have been also attempts to study the effect of landscape and patch level variables on animal groups other than birds. A study conducted in medium- and large-sized terrestrial mammals in a fragmented rain forest by Garmendia et al. (2013) suggests that number of species increases with increase in the size of the fragmented patch. Effect of landscape metrics on butterfly species richness was studied at different spatial scale and they found a significant impact of spatial scale on landscape-butterfly richness relationship (Rossi & Halder 2010).

To understand the community structure, composition and role of these forest patches, there is a need to measure of biodiversity. Species richness is the most common measure of biodiversity but it is difficult to measure the species richness of all flora and fauna present in the study area. Therefore, sample and survey surrogate or indicators of biodiversity are taken. There is an assumption that the diversity of these indicators is correlated with the diversity of other groups of species (Rossi & Halder 2010). Avian species diversity of a forest patch embedded in a landscape mosaic can be a good biodiversity indicator. The avian diversity in these forest patches will be dependent on various factors affecting the habitat and animals at different spatial scale. Local variables deciding the avian diversity are vegetation composition and structure, forest ground cover, canopy closure, size of the patch, and shape of the patch. At a landscape scale, variables affecting the avian diversity are the degree of isolation, connectivity, proximity to other forest fragments and patch density. Avian diversity can be observed simply as species richness. Species richness is the simplest method of characterizing a community's diversity. Species diversity is described as species richness, which is the number of species and evenness which is how equally abundant species are within the community. The community in which all the species present are equally abundant is considered to be even. Population with a large number of species and high evenness is considered to be more diverse (Magurran 1988). In this study, vegetation attributes of the sampled patches of BFC were calculated the vegetation attributes of the sampled forest patches of Bhopal Forest Circle (BFC), which is a part of Vindhyan and Malwa plateau. Bird species richness (observed) was determined. Undetected species of birds were also estimated using Chao 1 and abundance-based coverage (ACE) estimators. This study was conducted in BFC of Madhya Pradesh during 2015 to 2018. This study intends to estimate the species richness in the forest fragments of central Indian landscape. Forest fragments were selected following Island Biogeography Theory by MacArthur & Wilson (1967).

MATERIALS AND METHODS

Study area

The study was conducted in Bhopal Forest Circle of Madhya Pradesh forests from March 2015 to May 2018. BFC consists of six forest divisions: Bhopal, Sehore, Rajgarh, Vidisha, Raisen, and Obaidullaganj (Fig. 1; Image 1,2). All the divisions except Rajgarh come under Vindhyan Plateau agro-climatic region while Rajgarh comes under Malwa Plateau region. BFC consists of tropical dry deciduous forests. BFC has a total forest area of about 6,906.93km^2. Out of which reserved forest is 4,076.72km^2, the protected forest is 2,761.98km^{2,} and the unclassified forest is 68.23km^2 (MP Forest 2020).

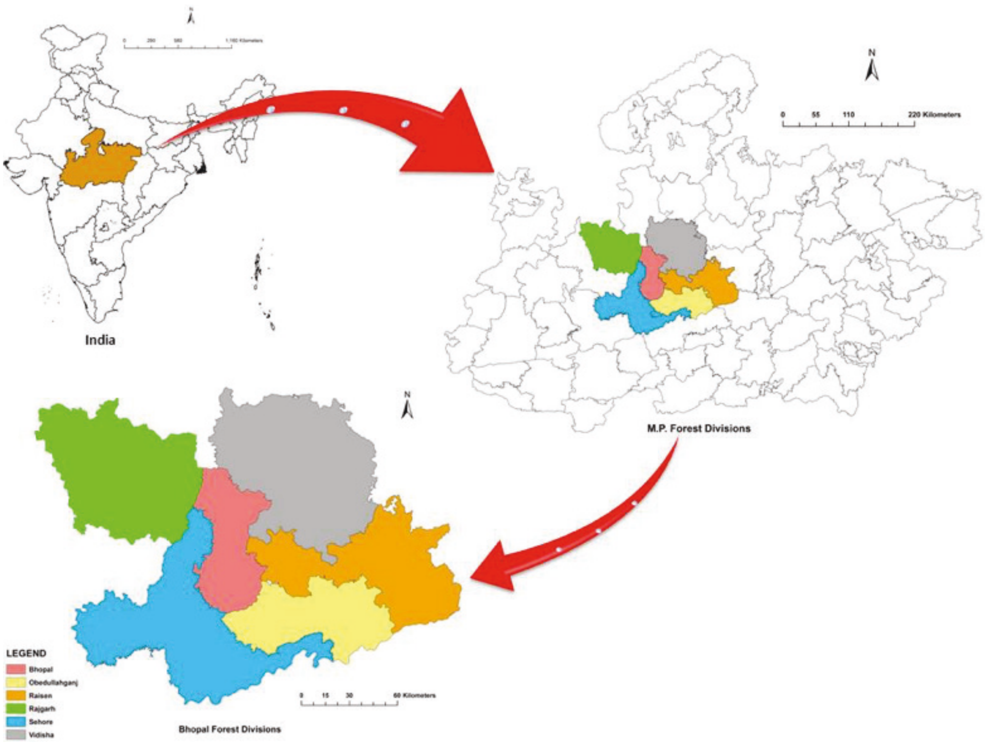

Figure 1. Geographic location of the study area in Bhopal Forest Circle in India.

Image 1 & 2. Location of the study area in Bhopal Forest Circle in India. © Madhya Pradesh Forest Department and Mr. Suman Raju.

Forest

Twenty-Two forest subtypes have been identified in Madhya Pradesh as per the classification by Champion & Seth (1968). These forest types belong to three groups, viz.: tropical dry deciduous forest, tropical moist deciduous forest, and tropical thorn forest. Tropical dry deciduous forest is the dominant group. Within sub-groups, dry teak forest is dominant (26.40%) followed by southern dry mixed deciduous forest (24.55%) and northern mix dry deciduous forest (18.55%). Rest of the forest types occupy less than 6% of forests cover (FSI, 2019). The BFC is characterized by tropical dry deciduous forest (Group 5). The major sub-groups of Group 5 and Group 6 forest types found in the study area encompass the following:

1. 5A/C 1b dry teak forest
2. 5A/C3 southern dry mixed deciduous forest
3. 5/DS1 dry deciduous scrub
4. 5/E1 *Anogeissus pendula* forest

The major species is Teak *Tectona grandis* in dry teak forests while *Butea monosperma*, *Diospyros melanoxylon*, *Acacia catechu*, *Anogeissus latifolia*, *Wrightia tinctoria*, *Lannea coromandelica*, and *Cassia fistula* are major species of mixed forests. *Anogeissus pendula* forest is dominated by *Anogeissus pendula* along with *Anogeissus latifolia.* Tree species found in dry deciduous scrub forests are *Butea monosperma*, *Acacia leucophloea, Lannea coromandelica*, *Diospyros melanoxylon*, and *Anogeissus latifolia*. In BFC, there are four protected areas; out of which three are wildlife sanctuaries (WS): Ratapani WS, Singhori WS, Narsinghgarh WS, and one is a national park: Van Vihar National Park (Table 1).

Table 1. Protected areas of BFC.

	Name of protected area	Establishment year	Area (km^2)	District
1	Narsinghgarh WS	1978	59.19	Rajgarh
2	Van Vihar NP	1979	4.45	Bhopal
3	Ratapani WS	1978	823.84	Raisen
4	Singhori WS	1976	287.91	Raisen

Sampling

The sampling unit of the study is a forest patch. A patch is defined as a relatively homogenous area which differs from its surrounding land use within the landscape (Peters et al. 2009). Patches were identified using Google Earth Pro, FRAGSTATS and ArcGIS 10.3. The forest patches were manually digitized using ArcGIS and Google Earth Pro and then they were used as the input file for FRAGSTATS program to get patch characteristics like their size and degree of isolation. A total of 98 patches were found in the study area. The area of these forest patches is in the range of 10–500 ha.

Sampling of patches

The basis of sampling was the area of patch and degree of isolation. Patches were grouped into four classes, i.e., (i) large area and high degree of isolation (8 patches), (ii) large area and less degree of isolation (36 patches), (iii) small area and high degree of isolation (6 patches), and (iv) small area and low degree of isolation (48 patches). Forest patches smaller than 100ha were considered as smaller patches while more than 100ha were considered larger patches. Forest patches having ENN distance of less than 1,500m from nearest forest were considered as patches with lower degree of isolation and vice versa. Out of the total 98 patches, 21 patches were sampled out using weighted stratified random sampling (Fig. 2). Samples were taken from each of the four classes based on their percentage of the

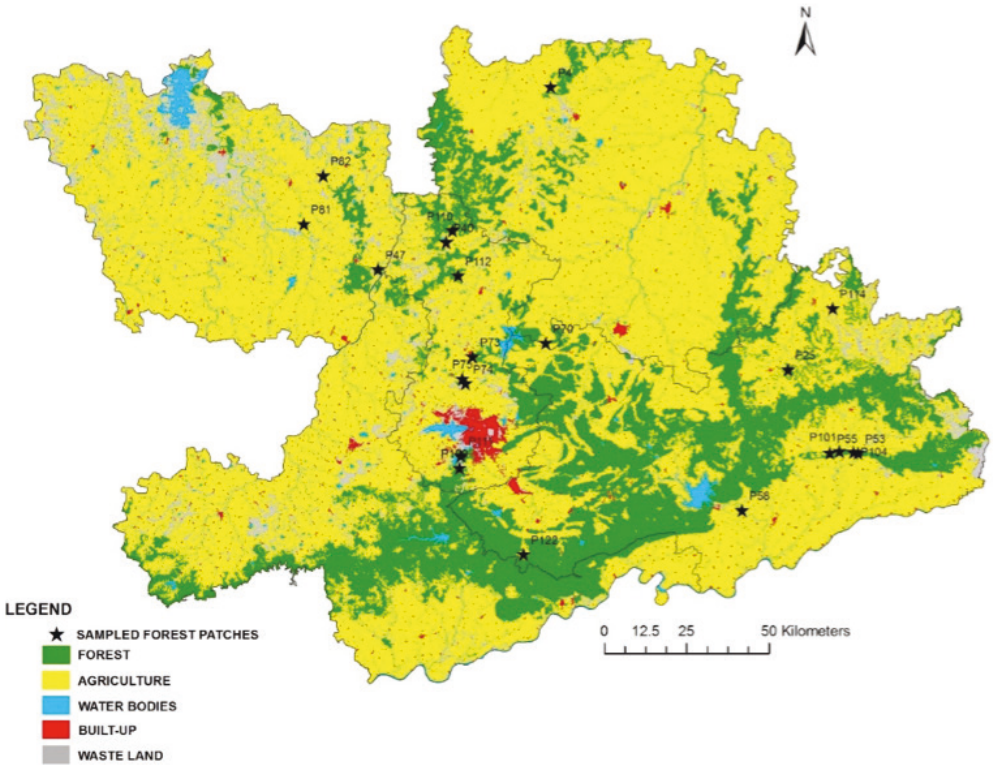

Figure 2. Sampled forest patches in the study area.

Table 2. Sampling of forest patches.

	Large size with high ENN	Large size with low ENN	Small size with high ENN	Small size with low ENN	Total number of patches
Patches	8	36	6	48	98
Total patches (%)	8.16	36.73	6.12	48.98	100
Samples	2	8	1	10	21

*ENN—Euclidean nearest neighbor distance

total number of patches found in the study area (Table 2).

During the field data collection surveys, if the patch was found to be not suitable for bird surveys due to higher forest degradation and their conversion into scrubland, resampling from the same strata was done. For example, if a sampled forest patch from large size and the large degree of isolation strata is found to be not suitable for the survey, another patch from the same group was randomly picked.

Field data collection

Bird survey

Breeding bird diversity of each forest patch was sampled using the point count method in which bird survey points were predefined within the forest patch, and at each point, bird surveys were done for 10 minutes each. Point count method was preferred over other methods since it is better suited for patchily distributed populations and for shy birds that would otherwise hide and escape detection. The points were selected within the forest patch following systematic random sampling. The minimum distance between two consecutive points was 500 m to avoid double counting. At each of these points, birds were surveyed visually as well as acoustically. The distance of the birds to the observer was also recorded using a laser rangefinder. In case of birds heard only, the distance was recorded in four distance classes, i.e., 0–10 m, 10–20 m, 20–50 m, and >50m. Each point was surveyed for three consecutive days during one replication. Bird surveys were avoided during cloudy or rainy days. Surveys were carried out in mornings 06.00–09.00 h and in evenings 16.00–18.00 h.

Avian species richness

Species richness is the simplest method of characterising community/population diversity. Species richness is the basis of many ecological models like Island Biogeography Theory (McArthur & Wilson 1967), the intermediate disturbance hypothesis (Connell 1978), as well as more recent models of neutral theory (Hubbell 2001), and meta-community structure (Leibold et al. 2005). These theories try to generate quantitative predictions of the number of coexisting species in a community; however, though it is a simple measure of diversity, it is still difficult to estimate accurately. It is always an underestimation of the surveyed community. To correct for this underestimation of species richness, there are many sampling models and estimators of asymptotic richness to estimate the undetected species (Gotelli et al. 2011). For the present study, Chao 1 (Eq. 1), ACE (Eq. 2) and Jackknife estimators were used to estimate the undetected species of birds. These estimators are used for abundance data. Therefore, the estimators were used to calculate the estimated species richness using the Palaeontology Statistics (PAST 3.0) program (Hammer et al. 2001).

a. *Chao 1*

Chao1 = S + F1(F1 - 1) / (2 (F2 + 1)), where F1 is the number of singleton species and F2 the number of doubleton species.

b. ACE: Abundance Coverage-based Estimator of species richness

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F1}{C_{ace}} * \gamma_{ace}{}^2 \quad (1)$$

Where:

$S_{rare} = \sum_{k=1}^{10} F_k$ is the number of rare species in a sample (each with 10 or fewer individuals).

$S_{abund} = \sum_{k=11}^{S_{obs}} F_k$ is the number of abundant species in a sample (each with more than 10 individuals)

$n_{rare} = \sum_{k=1}^{10} kF_k$ is the total number of individuals in the rare species.

$C_{ace} = 1 - f_1/n_{rare}$ is the sample cover estimate which is the proportion of all individuals in rare species that are not singletons.

$\gamma_{ace}{}^2$ = is the coefficient of variation ,

$$\gamma_{ace}{}^2 = max\left[\frac{S_{rare}}{C_{ace}} \frac{\sum_{k=1}^{10} k(k-1)f_k}{(n_{rare})(n_{rare}-1)} - 1{,}0\right] \quad (2)$$

RESULTS AND DISCUSSION

Therefore, in this study, 21 forest patches were surveyed for bird species diversity. A total of 131 bird species were recorded in the study area (21 forest patches). Table 3 classifies these species as Resident or Migratory; 31 out of 131 species were migratory.

Avian species richness estimation

The total number of species recorded in the patches during the field surveys is the observed species richness. Species richness of each patch was calculated using the bird survey data, but the observed species richness is not the true number of species present in the forest patches. There are always bird species which get undetected due to various reasons. To correct the species richness for all these forest patches, species richness estimators for abundance data were applied to the data. Chao 1 and ACE estimators were used in PAST 3.0 software. Non-parametric species estimators like Chao 1 and ACE, extrapolate the observed data to find the 'true' number of species present in the study area (Colwell & Coddington 1994). These estimators use the number of rare species found in the sample to estimate more number of species likely to get undetected. Species richness estimators for abundance data were applied to the survey data to estimate the improved species richness in these forest patches. Chao 1 and ACE estimators were used in PAST 3.0 software (Table 4).

To count in undetected species and estimate the true species richness, species richness estimators were applied to the overall species richness data (Table 5). The estimators used were Chao 1, Jackknife 1, Jackknife 2, and Bootstrapping.

DISCUSSION

Continuous forest areas outside protected areas are always at risk of habitat destruction and fragmentation, which leads to biodiversity loss and local extinction of certain species too. There have been various studies globally on fragmented forest patches (natural and plantations). There are very few studies from the Indian subcontinent, which are restricted mainly to plantations (Daniels et al. 1992; Bhagwat et al. 2005; Raman 2006; Bali et al. 2007); however, forest fragments outside-protected areas in the central Indian landscape have not been studied for its role in conserving biodiversity. In this study, avian diversity of these isolated forest patches has been studied to understand the role these forest patches can play in conserving biodiversity in an agrarian landscape.

The results from this study suggest that forest patches with larger sizes such as Binapur (size= 166ha, Chao 1=

Table 3. Bird species recorded during the survey from the 21 forest patches of central Indian forest landscape.

	Common name	Scientific name	Resident or migratory
1	Ashy-crowned Sparrow-lark	*Eremopterix griseus* (Scopoli, 1786)	Resident
2	Ashy Drongo	*Dicrurus leucophaeus* (Vieillot, 1817)	Migratory
3	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	Resident
4	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	Resident
5	Asian Palm-swift	*Cypsiurus balasiensis* (Gray, 1829)	Resident
6	Indian Paradise Flycatcher	*Terpsiphone paradise* (Linnaeus, 1758)	Resident
7	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	Migratory
8	Barred Buttonquail	*Turnix suscitator* (Gmelin, 1789)	Resident
9	Bay-backed Shrike	*Lanius vittatus* (Valenciennes, 1826)	Migratory
10	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	Resident
11	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	Resident
12	Black Kite	*Milvus migrans* (Boddaert, 1783)	Resident
13	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	Migratory
14	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	Resident
15	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	Resident
16	Blue Rock-thrush	*Monticola solitarius* (Linnaeus, 1758)	Migratory
17	Blyth's Reed-warbler	*Acrocephalus dumetorum* (Blyth, 1849)	Migratory
18	Bonelli's Eagle	*Aquila fasciata* (Vieillot, 1822)	Resident
19	Booted Warbler	*Iduna caligata* (Lichtenstein, 1823)	Migratory
20	Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	Resident
21	Indian Pygmy Woodpecker	*Dendrocopos nanus* (Vigors, 1832)	Resident
22	Brown Rockchat	*Cercomela fusca* (Blyth, 1851)	Resident
23	Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	Migratory
24	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	Resident
25	Chestnut-bellied Sandgrouse	*Pterocles exustus* (Temminck, 1825)	Resident
26	Chestnut-shouldered Petronia	*Gymnoris xanthocollis* (Burton, 1838)	Resident
27	Chestnut-tailed Starling	*Sturnia malabarica* (Gmelin, 1789)	Migratory
28	Common Babbler	*Turdoides caudate* (Dumont, 1823)	Resident
29	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	Migratory
30	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	Resident
31	Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	Resident
32	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	Resident
33	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	Migratory
34	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	Resident
35	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	Migratory
36	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	Resident
37	Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	Resident
38	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	Resident
39	Crested Bunting	*Emberiza lathami* (Gray, 1831)	Migratory
40	Crested Lark	*Galerida cristata* (Linnaeus, 1758)	Resident
41	Crested Treeswift	*Hemiprocne coronate* (Tickell, 1833)	Resident
42	Dusky Crag Martin	*Ptyonoprogne concolor* (Sykes, 1832)	Resident
43	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	Resident
44	Eurasian Collared-dove	*Streptopelia decaocto* (Frivaldszky, 1838)	Resident

	Common name	Scientific name	Resident or migratory
45	Indian Golden Oriole	*Oriolus Kundoo* (Sykes, 1832)	Resident
46	Great Tit	*Parus major* (Linnaeus, 1758)	Resident
47	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	Resident
48	Green Bee-eater	*Merops orientalis* (Latham, 1802)	Resident
49	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	Migratory
50	Grey-bellied Cuckoo	*Cacomantis passerines* (Vahl, 1797)	Migratory
51	Grey-breasted Prinia	*Prinia hodgsonii* (Blyth, 1844)	Resident
52	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	Resident
53	Grey-necked Bunting	*Emberiza buchanani* (Blyth, 1844)	Migratory
54	Griffon Vulture	*Gyps fulvus* (Hablizl, 1783)	Migratory
55	House Crow	*Corvus splendens* (Vieillot, 1817)	Resident
56	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	Resident
57	Hume's Leaf-warbler	*Phylloscopus humei* (Brooks, 1878)	Migratory
58	Indian Bushlark	*Mirafra erythroptera* (Blyth, 1845)	Resident
59	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	Resident
60	Indian Nightjar	*Caprimulgus asiaticus* (Latham, 1790)	Resident
61	Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	Resident
62	Indian Pitta	*Pitta brachyura* (Linnaeus, 1766)	Migratory
63	Indian Pond-heron	*Ardeola grayii* (Sykes, 1832)	Resident
64	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	Resident
65	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	Resident
66	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	Resident
67	Jerdon's Leafbird	*Chloropsis jerdoni* (Blyth, 1844)	Resident
68	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	Resident
69	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	Resident
70	Jungle Prinia	*Prinia sylvatica* (Jerdon, 1840)	Resident
71	Large Cuckooshrike	*Coracina macei* (Lesson, 1831)	Resident
72	Large Grey Babbler	*Argya malcolmi* (Sykes, 1832)	Resident
73	Laughing Dove	*Spilopelia senegalensis* (Linnaeus, 1766)	Resident
74	Lesser Whitethroat	*Sylvia curruca* (Linnaeus, 1758)	Migratory
75	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	Resident
76	Long-billed Vulture	*Gyps indicus* (Scopoli, 1786)	Resident
77	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	Resident
78	Oriental Honey-buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	Resident
79	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	Resident
80	Oriental Turtle-dove	*Streptopelia orientalis* (Latham, 1790)	Migratory
81	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	Resident
82	Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	Resident
83	Painted Francolin	*Francolinus pictus* (Jardine & Selby, 1828)	Resident
84	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	Migratory
85	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos* (Latham, 1790)	Resident
86	Peregrine Falcon	*Falco peregrinus* (Tunstall, 1771)	Resident
87	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	Migratory
88	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	Resident
89	Plain Prinia	*Prinia inornata* (Sykes, 1832)	Resident

	Common name	Scientific name	Resident or migratory
90	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	Resident
91	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	Resident
92	Red Avadavat	*Amandava amandava* (Linnaeus, 1758)	Resident
93	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	Migratory
94	Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	Resident
95	Red-rumped Swallow	*Cecropis daurica* (Linnaeus, 1771)	Resident
96	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Resident
97	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Resident
98	River Tern	*Sterna aurantia (*Gray, 1831)	Resident
99	Rock Bush-quail	*Perdicula argoondah* (Sykes, 1832)	Resident
100	Rock Dove	*Columba livia* (Gmelin, 1789)	Resident
101	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	Resident
102	Rosy Starling	*Pastor roseus* (Linnaeus, 1758)	Migratory
103	Rufous-fronted Prinia	*Prinia buchanani* (Blyth, 1844)	Resident
104	Rufous-tailed Lark	*Ammomanes phoenicura* (Franklin, 1831)	Resident
105	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	Resident
106	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	Resident
107	Shikra	*Accipiter badius* (Gmelin, 1788)	Resident
108	Short-toed Snake-eagle	*Circaetus gallicus* (Gmelin, 1788)	Resident
109	Sirkeer Malkoha	*Taccocua leschenaultia* (Lesson, 1830)	Resident
110	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Resident
111	Indian Spot-billed Duck	*Anas poecilorhyncha* (Forster, 1781)	Resident
112	Spotted Dove	*Spilopelia suratensis* (Gmelin, 1789)	Resident
113	Sulphur-bellied Warbler	*Phylloscopus griseolus* (Blyth, 1847)	Migratory
114	Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	Migratory
115	Tickell's Blue-flycatcher	*Cyornis tickelliae* (Blyth, 1843)	Resident
116	Tickell's Leaf-warbler	*Phylloscopus affinis* (Tickell, 1833)	Migratory
117	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	Migratory
118	Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)	Migratory
119	Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	Migratory
120	White-bellied Drongo	*Dicrurus caerulescens* (Linnaeus, 1758)	Resident
121	White-browed Fantail	*Rhipidura aureola* (Lesson, 1830)	Resident
122	White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	Resident
123	White-naped Woodpecker	*Chrysocolaptes festivus* (Boddaert, 1783)	Resident
124	White-rumped Vulture	*Gyps bengalensis* (Gmelin, 1788)	Resident
125	White-spotted Fantail	*Rhipidura albogularis* (Lesson, 1832)	Resident
126	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Resident
127	Wire-tailed Swallow	*Hirundo smithii* (Leach, 1818)	Resident
128	Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783)	Resident
129	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	Resident
130	Yellow-eyed Babbler	*Chrysomma sinense* (Gmelin, 1789)	Resident
131	Yellow-footed Green-pigeon	*Treron phoenicopterus* (Latham, 1790)	Resident

*Source of Latin names: IUCN Redlist (IUCN 2020).

Table 4. Observed species richness and estimated species richness of patches using Chao 1 and ACE estimators.

	Patch classes	Patch name	Species richness observed	Estimated species richness (Chao1)	Estimated species richness (ACE)
1	Small size with low ENN	Ghatkhedi	38	49	46.45
2		Lalghati	57	62	65.43
3		Satgarhi	53	56.75	59.76
4		Barkhedi	35	39	40.41
5		Durang	55	66.375	68.23
6		Nasipur	49	52.27	55.86
7		Itkhedi	43	44.5	46.79
8		Manakwada	38	48.5	43.83
9	Small size with high ENN	Padajhir	41	47	48.46
10		Ghot	50	53.27	57.14
11		Lasudli	57	65.25	66.97
12		Durgapura	35	37.62	40.55
13	Large size with low ENN	Singota	42	45	46.155
14		Kerwa	43	48	50.82
15		Pathariya	51	54	53.77
16		Kalyanpura	61	80	74.38
17		Narsinghgarh	27	28	29.76
18		Sayar	61	78	75.83
19		Binapur	64	73	75.8
20		Kishanpur	46	50	51.24
21	Large size with high ENN	Amgawa	48	51	51.3

*ENN—Euclidean nearest neighbor

Table 5. Estimated species richness of the study area.

	Estimator	Estimated species richness	Standard error
1	Chao 1	154.1	11.7
2	Jackknife 1	156.71	7.9
3	Jackknife 2	168.25	-
4	Bootstrapping	143.02	4.4

73), Sayar (size= 107ha, Chao 1= 78), and Kalyanpura (size= 133ha, Chao 1= 80), were having higher avian diversity except for forest patches Narsinghgarh (size= 393ha, Chao 1= 28), Singota (size= 184ha, Chao 1= 45) with higher degree of anthropogenic disturbances in the form of cattle grazing, fuelwood collection, and collection of non-timber forest products such as Mahua *Madhuca latifolia*, Tendu *Diospyros melanoxylon* leaves, and natural gum. Smaller forest patches were found to have fewer bird species; however, smaller forest patches with less degree of anthropogenic disturbances such as Lalghati (size= 99ha, Chao 1= 62), Lasudli (size= 16ha, Chao 1= 65), Ghot (size= 36ha, Chao 1= 53), and Nasipur (size= 23ha, Chao 1= 52) were more diverse than other smaller patches. These smaller patches were more protected due to being a sacred grove (Lalghati and Lasudli) and private ownership (Ghot and Nasipur). A study conducted in Columbian Andes in 2010 studied the effects of landscape structure on bird's richness. They found that patch area is a key driver of species richness. Species richness increases towards large patches but the effect of patch area decreases when other factors like human disturbance come into scenario (Aubad et al. 2010). In various other studies, it has been found that patch size affects the avian diversity significantly (Garmendia et al. 2013; Herrando & Brotons 2002; Aubad et al. 2010). A study conducted on sacred groves of Western Ghats suggests that patch size does not influence the diversity of birds, trees, and macro fungi (Bhagwat et al. 2005). This study suggests that the avian diversity in forest patches in an agrarian landscape depends on patch size and protection status of these patches. Forest patches with more protection due to its status of sacred grove and private ownership had more avian diversity even when the size of the patch was smaller.

CONCLUSION

In studies around the world, forest fragments were found to be rich in biodiversity. They provide habitat to various kind of plant and animal species. Therefore, there is a need to conserve and connect these forest patches embedded in the landscape matrix. The present study estimates the biodiversity of fragmented forest patches of BFC. Results of the study suggest that forest patches can support good bird diversity even after a high anthropogenic pressure in the form of grazing, fuelwood collection, and NTFPs collection. Nevertheless, patches with anthropogenic disturbances were found to have less diversity of birds in comparison to patches with lesser disturbance. Patch size certainly have a positive effect on bird diversity; however, human disturbance also affects the avian community dynamics in these forest patches. This study recorded 131 species of birds from 21 forest patches from the Vindhyan plateau. This is a good number of species, since the total number of species found in the two nearby wildlife sanctuaries are:

1. Ratapani Wildlife Sanctuary (153 species, 10 checklists) and

2. Narsinghgarh Wildlife Sanctuary (65 species, 2 checklists) (ebird 2020).

The study area is poorly studied for its biodiversity. These forest patches are of different sizes and have a different degree of isolation. A few forest patches like Ghot (privately owned) and Lasudli (sacred grove) are smaller but have high avian diversity due to their protected status. On the other hand, patches such as Pathariya and Amgawa are larger patches with low avian diversity due to higher anthropogenic pressure in the form of grazing, fuelwood collection, and non-timber forest products collection. Therefore, it can be suggested that the diversity in forest patch or fragments not just depends on its size and degree of isolation but also on the degree of anthropogenic disturbance. The ideal scenario would be larger patch size, a lesser degree of isolation (i.e., higher connectivity) and least anthropogenic pressure. The avian diversity was good in forest patches as well as the overall study area despite the anthropogenic pressure. This study fulfills the gap of biodiversity data from the study area. Even the wildlife sanctuaries in the study area have been poorly studied for its biodiversity, which makes this study important. This study also focuses on the need to conserve the forest patches by connecting the forest fragments and reducing the anthropogenic pressure as they play a vital role in providing habitat to various flora and fauna. Protecting these forest patches will help in conserving the biodiversity of the whole landscape.

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