The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under Creative Commons Attribution 4.0 International License unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

Journal of Threatened Taxa
Building evidence for conservation globally
www.threatenedtaxa.org
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

COMMUNICATION

AVIAN DIVERSITY IN A FRAGMENTED LANDSCAPE OF CENTRAL INDIAN FORESTS (BHOPAL FOREST CIRCLE)

Amit Kumar, Yogesh Dubey & Advait Edgaonkar

26 April 2021 | Vol. 13 | No. 5 | Pages: 18177–18188
DOI: 10.11609/jott.6528.13.5.18177-18188

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various
For reprints, contact <ravi@threatenedtaxa.org>
Avian diversity in a fragmented landscape of central Indian forests (Bhopal Forest Circle)

Amit Kumar1, Yogesh Dubey2, & Advaite Edgaonkar3

1-2,3 Indian Institute of Forest Management, 357, Bhadbhada Road, Nehru Nagar, Bhopal, Madhya Pradesh 462003, India.
1:amitkumarkush834@gmail.com (corresponding author), 2:ydubey@ifim.ac.in, 3:advaite@ifim.ac.in

Abstract: With increasing fragmentation of natural areas and a dramatic reduction of forest cover in various 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.
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 6,906.93km². Out of which reserved forest is 4,076.72km², the protected forest is 2,761.98km² and the unclassified forest is 68.23km² (MP Forest 2020).
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 subgroups, 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/C1b 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).

### 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

### Table 1. Protected areas of BFC.

| Name of protected area | Establishment year | Area (km²) | District |
|------------------------|--------------------|------------|----------|
| 1 Narsinghgarh WS      | 1978               | 59.19      | Rajgarh  |
| 2 Van Vihar NP         | 1979               | 4.45       | Bhopal   |
| 3 Ratapani WS          | 1976               | 823.84     | Raisen   |
| 4 Singhori WS          | 1976               | 287.91     | Raisen   |
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 >50 m. 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).

### Chao 1

\[
\text{Chao}1 = S + F1(F1 - 1) / (2 (F2 + 1)), \]

where \(F1\) is the number of singleton species and \(F2\) the number of doubleton species.

### ACE: Abundance Coverage-based Estimator of species richness

\[
S_{ace} = S_{abund} + \frac{S_{rare}}{c_{ace}} + \frac{F1}{c_{ace}} \gamma_{ace}^2
\]

Where:

- \(S_{rare}\) is the number of rare species in a sample (each with 10 or fewer individuals).
- \(S_{abund}\) is the number of abundant species in a sample (each with more than 10 individuals).
- \(S_{total}\) is the total number of individuals in the rare species.
- \(c_{ace}\) 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,

\[
\gamma_{ace}^2 = \max \left[ \frac{S_{rare} \sum_{k=1}^{10} k(k-1)f_k}{c_{ace} (n_{rare})(n_{rare}-1)} - 1.0 \right]
\]

### 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 Baya-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 (Boddart, 1783)                      | Resident              |
| 13 Black Redstart                | Phoenicurus ochruros (Gmelin, 1774)                 | Migratory             |
| 14 Black-rumped Flameback        | Dinopium benghalense (Linnaeus, 1758)               | Resident              |
| 15 Black-winged Kite             | Eianus caeruleus (Desfontaines, 1789)               | Resident              |
| 16 Blue Rock-thrush              | Monticola solitarius (Linnaeus, 1758)               | Migratory             |
| 17 Blyth’s Reed-warbler          | Accipiter bledeni (Blyth, 1849)                     | Migratory             |
| 18 Bonelli’s Eagle               | Aquila fasciata (Vieillot, 1822)                    | Resident              |
| 19 Booted Warbler                | Iudna caligata (Lichtenstein, 1823)                 | Migratory             |
| 20 Brahminy Starling             | Sturnia pagadum (Gmelin, 1789)                      | Resident              |
| 21 Indian Pigeon 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 caudatus (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 tephia (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 pendicentus (Gmelin, 1789)             | Resident              |
| 38 Coppersmith Barbet            | Psilopogon haemacephalus (Müller, 1776)             | Resident              |
| 39 Crested Bunting               | Emberiza iathami (Gray, 1831)                       | Migratory             |
| 40 Crested Lark                  | Galerida cristata (Linnaeus, 1758)                  | Resident              |
| 41 Crested Treeswift             | Hemiprocne coronae (Tickell, 1833)                  | Resident              |
| 42 Dusky Crag Martin             | Pynaprogne concolor (Sykes, 1832)                   | Resident              |
| 43 Egyptian Vulture              | Neophron percnopterus (Linnaeus, 1758)              | Resident              |
| 44 Eurasian Collared-dove        | Streptopelia decaocto (Frivaldszy, 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 trachiloides (Sundevall, 1837)         | Migratory             |
| 50 Grey-bellied Cuckoo     | Cacomantis passerinens (Vahl, 1797)                 | Migratory             |
| 51 Grey-breasted Prinia    | Prinia hodgsoni (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 erythropsa (Blyth, 1845)                    | Resident              |
| 59 Indian Grey Hornbill    | Dyceros briostris (Scopoli, 1786)                   | Resident              |
| 60 Indian Nightjar         | Coprimulus asiaticus (Latham, 1790)                | Resident              |
| 61 Indian Peafowl          | Pavo cristatus (Linnaeus, 1758)                    | Resident              |
| 62 Indian Pitta            | Pita brachysa (Linnaeus, 1766)                      | Migratory             |
| 63 Indian Pond-heron       | Ardeola grayii (Sykes, 1832)                        | Resident              |
| 64 Indian Robin            | Saxicola cuculata (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 ptilorhynchos (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 rufalus (Vieillot, 1818)                     | Resident              |
| 83 Painted Francolin       | Francolinus pictus (Jardine & Selby, 1828)         | Resident              |
| 84 Painted Stork           | Mycteris 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 argoandah (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 galicus (Gmelin, 1788)                    | Resident              |
| 109 Sirkeer Malkoha          | Taccocua leschenaulta (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 saturensis (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 supercilias (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 aurea (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| Leioptilus maharattensis (Latham, 1801)              | Resident              |
| 130 Yellow-eyed Babbler      | Chrysomma sinense (Gmelin, 1789)                    | Resident              |
| 131 Yellow-footed Green-pigeon| Treron phoenicopephalus (Linnaeus, 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) |
|------------------------|-------------|---------------------------|-----------------------------------|----------------------------------|
| Small size with low ENN| Ghatkhedi   | 38                        | 49                                | 46.45                            |
|                        | Lalghati    | 57                        | 62                                | 65.43                            |
|                        | Satgarhi    | 53                        | 56.75                             | 59.76                            |
|                        | Barkhedi    | 35                        | 39                                | 40.41                            |
|                        | Durang      | 55                        | 66.375                            | 68.23                            |
|                        | Nasipur     | 49                        | 52.27                             | 55.86                            |
|                        | Itkhedi     | 43                        | 44.5                              | 46.79                            |
|                        | Manalkwada  | 38                        | 48.5                              | 43.83                            |
| Small size with high ENN| Padajhir    | 41                        | 47                                | 48.46                            |
|                        | Ghot        | 50                        | 53.27                             | 57.14                            |
|                        | Lasudli     | 57                        | 65.25                             | 66.97                            |
|                        | Durgapura   | 35                        | 37.82                             | 40.55                            |
| Large size with low ENN| Singota     | 42                        | 45                                | 46.155                           |
|                        | Kerwa       | 43                        | 48                                | 50.82                            |
|                        | Pathariya   | 51                        | 54                                | 53.77                            |
|                        | Kalyanpura  | 61                        | 80                                | 74.38                            |
|                        | Narsinghgarh| 27                        | 28                                | 29.76                            |
| Large size with high ENN| Sayar       | 61                        | 78                                | 75.83                            |
|                        | Binapur     | 64                        | 73                                | 75.8                             |
|                        | Kishanpur   | 46                        | 50                                | 51.24                            |
| 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 |
|-------------|---------------------------|----------------|
| Chao 1      | 154.1                     | 11.7           |
| Jackknife 1 | 156.71                    | 7.9            |
| Jackknife 2 | 168.25                    | -              |
| 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.

REFERENCES

Andren, H. (1994). Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 65:355–366.

Aubad, J., P. Aragón, & M.A. Rodríguez (2010). Human access and landscape structure effects on Andean forest bird richness. Acta Oecologica 36(4): 396-402.

Bali, A., A. Kumar & J. Krishnaswamy (2007). The mammalian communities in coffee plantations around a protected area in the Western Ghats, India. Biological Conservation 139(1–2): 93–102.

Bennett, A.F., S.A. Hinsley, P.E. Bellamy, R.D. Sweetnam & R. Mac Nally (2004). Do regional gradients in land-use influence richness, composition and turnover of bird assemblages in small woods? Biological Conservation 119(2): 191–206.

Bhagwat, S.A., C.G. Kushalappa, P.H. Williams & N.D. Brown (2005). A landscape approach to biodiversity conservation of sacred groves in the Western Ghats of India. Conservation Biology 19(6): 1853–1862.

Champion, S.H. & S.K. Seth (1968). A revised survey of the forest types of India. Govt. of India Publications, 297–299pp.

Chazdon, R.L., C.A. Harvey, O. Komar, D.M. Griffith, B.G. Ferguson, M. Martínez-Ramos & S.M. Philpott (2009). Beyond reserves: a research agenda for conserving biodiversity in human-modified tropical landscapes. Biotropica 41(2): 142–153.

Colwell, R.K. & J.A. Coddington (1994). Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society B: Biological Sciences 345: 101–118.

Connell, J.H. (1978). Diversity in tropical rainforests and coral reefs. Science 199(4335): 1302–1310.

Daniels, R.J., N.V. Joshi & M. Gadgil (1992). On the relationship between bird and woody plant species diversity in the Uttara Kannada district of south India. Proceedings of the National Academy of Sciences 89(12): 5311–5315.

eBird (2020). eBird: An online database of bird distribution and abundance [web application]. eBird, Cornell Lab of Ornithology, Ithaca, New York. Available: http://www.ebird.org. Accessed on 17 July 2020.

Feeley, K.J., T.W. Gillespie, D.J. Lebbin & H.S. Walter (2007). Species characteristics associated with extinction vulnerability and nestedness rankings of birds in tropical forest fragments. Animal Conservation 10(4): 493–501.

Garmendia, A., V. Arroyo-Rodríguez, A. Estrada, E.J. Naranjo & K.E. Stoner (2013). Landscape and patch attributes impacting medium-and large-sized terrestrial mammals in a fragmented rain forest. Journal of Tropical Ecology 29(4): 331–344.

Gotelli, N.J. & R.K. Colwell (2011). Estimating species richness. Biological Diversity: Frontiers in Measurement and Assessment 12: 39–54.

Gotelli, N.J. & G.R. Graves (1996). Null models in ecology. Smithsonian Institution.

Hammer, Ø., D.A.T. Harper, P.D. Ryan (2001). PAST: Paleontological statistics software package for education and data analysis. Paleontologia Electronica 4(1): 9.

Herrando, S. & L. Brotons (2002). Forest bird diversity in Mediterranean areas affected by wildfires: a multi-scale approach. Ecography 25(2): 161–172.

Hill, J.K., M.A. Gray, C.V. Khen, S. Benedick, N. Tawatao & K.C. Hamer (2011). Ecological impacts of tropical forest fragmentation: how consistent are patterns in species richness and
Avian diversity in a fragmented landscape of Bhopal Forest Circle

Kumar et al.

18188

Author details: AMIT KUMAR is a PhD scholar at Indian Institute of Forest Management (Research Centre), Bhopal, registered at Forest Research Institute University, Dehradun. He holds a post graduation degree in Environment Management from Forest Research Institute University, Dehradun. He is studying the impact of plot level and patch level variables on avian community in fragmented forest patches of Bhopal Forest Circle, Madhya Pradesh for his PhD. Dr. YOGESH K. DUBEY works as a Professor with Indian Institute of Forest Management, Bhopal in the faculty area of Ecosystem and Environment Management. Dr. Yogesh is Chairperson of PG programs of the Institute. He holds a master Degree in Wildlife Science and PhD in Forestry from FRI Deemed University. His Doctoral work was in Tadoba Andhari Tiger Reserve, Maharashtra. At IIFM, he is also the Chairperson of Center for Human wildlife conflict Management. He research interests are in areas related to wildlife conservation, Biodiversity inclusive impact assessment and Sustainable Ecotourism. Dr. ADVAIT EDGAONKAR is Assistant Professor at IIFM, Bhopal. He teaches wildlife management and impact evaluation, and does research on ecosystem services.

Hubbell, S.P. (2001). *The unified neutral theory of biodiversity and biogeography (MPB-32)*. Princeton University Press.

Jennings, S.B., N.D. Brown & D. Sheil (1999). Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. *Forestry: An International Journal of Forest Research* 72(1): 59–74.

Leibold, M.A., M. Holyoak, N. Mouquet, P. Amarasekare, J.M. Chase, M.F. Hoopes & M. Loreau (2004). The metacommunity concept: a framework for multi-scale community ecology. *Ecology Letters* 7(7): 601–613.

MacArthur, R.H. & E.O. Wilson (1963). An equilibrium theory of insular zoogeography. *Evolution* 17(4): 373–387.

Magurran, A.E. (1988). Diversity indices and species abundance models, pp. 7–45. In: *Ecological diversity and its measurement*. Springer, Dordrecht.

Martensen, A.C., R.G. Pimentel & J.P. Metzger (2008). Relative effects of fragment size and connectivity on bird community in the Atlantic Rain Forest: implications for conservation. *Biological Conservation* 141(9): 2184–2192.

Morris, R.J. (2010). Anthropogenic impacts on tropical forest biodiversity: a network structure and ecosystem functioning perspective. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 365(1558): 3709–3718.

MP forest website: http://www.mp.gov.in/en/web/guest/forest. Accessed on 18 July (2018).

Oliver, A.J., C. Hong-Wa, J. Devonshire, K.R. Osea, G.F. Rivas & M.K. Gahl (2011). Avifauna richness enhanced in large, isolated urban parks. *Landscape and Urban Planning* 102(4): 215–225.

Peters, D.P., J.R. Gosz & S.L. Collins (2009). Boundary dynamics in landscapes, pp. 458–463. In: Levin, S.A. (ed.). The Princeton Guide to Ecology. Princeton, NJ:Princeton University Press.

Raman, T.S. (2006). Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. *Forest Diversity and Management*. Springer, Dordrecht.

Rossi, J.P. & I. Van Halder (2010). Towards indicators of butterfly biodiversity based on a multiscale landscape description. *Ecological Indicators* 10(2): 452–458.

Shahabuddin, G., & J.W. Terborgh (1999). Frugivorous butterflies in Venezuelan forest fragments: abundance, diversity and the effects of isolation. *Journal of Tropical Ecology* 15(6): 703–712.

Suarez-Rubio, M. & J.R. Thomlinson (2009). Landscape and patch-level factors influence bird communities in an urbanized tropical island. *Biological Conservation* 142(7): 1311–1321.

Wiens, J.A. (1995). Habitat fragmentation: island v landscape perspectives on bird conservation. *Ibis* 137(s1).

Wilson, E.O. & R.H. MacArthur (1967). *The Theory of Island Biogeography*. Princeton University Press.

IUCN 2020. The IUCN Red List of Threatened Species. Version 2020-2. https://www.iucnredlist.org. Downloaded on 09 July 2020.
