

Impact of Habitat Fragmentation on Bird Species Diversity: A Case Study Approach for Indian School-Based Field Learning

GEETIKA

*Associate Professor, (Zoology) S.P.N.K.S. Govt (PG) College,
Dausa Rajasthan*

Abstract

The speed at which Indian landscapes undergo transformation reaches its highest level since historical records began. The natural habitats which birds need for their entire life cycle from breeding to their daily activities face destruction because of three practices: forest clearing for agricultural and infrastructure development and wetland drainage for urban growth and grassland conversion into single crop agricultural fields. The article studies how habitat fragmentation decreases bird species diversity through three scientific frameworks which include island biogeography theory and landscape ecology research and various documented case studies from different regions of India. The study investigates how fragmentation affects bird populations through four specific methods which include reducing patch sizes and creating edge effects and losing corridors and isolating populations. The article presents a specific argument which supports this topic as the main focus for school-based field learning throughout India because it matches with the experiential and inquiry-based educational approach prescribed by the National Education Policy 2020. The researchers suggest practical case study methodologies together with citizen science integration and region-specific field protocols as effective methods to teach Indian secondary and undergraduate students about scientific research through real-world ecological experiences.

Keywords: *bird species diversity, field learning, landscape ecology, habitat fragmentation, island biogeography, Indian schools*

I. Introduction

The forest used to be continuous for 100 kilometers but now shows multiple destructive paths, which have created village borders, replaced forest areas with agricultural fields, and installed power lines throughout the remaining territory. The original ecosystem now exists as separate ecosystem parts, which each become smaller and more vulnerable to environmental stress than their original size. The process of habitat fragmentation functions as a major force that causes species extinction throughout the globe.

Birds serve as the most effective species for measuring how habitat fragmentation impacts their environment. Birds create accessible detection methods through their movement and vocalizations and their existing research base, which enables scientists to monitor changes in their populations. Forest fragments experience species loss because their interior-dwelling species need large territories, edge protection, and undisturbed nesting sites. The forest patch appears green from a distance, but its ecological function has been compromised.

India presents one of the most urgent and complex contexts for studying this phenomenon. The country supports over 1,300 bird species across a remarkable range of habitats — from the Himalayan alpine zone to the tropical evergreen forests of the Western Ghats, from the Thar Desert to the Sundarbans mangroves (Praveen et al., 2016). At the same time, India's human population and economy are growing rapidly, driving land-use change at a scale and pace that creates fragmentation across virtually every major biome. The Forest Survey of India (FSI, 2021) recorded India's total forest and tree cover at 80.9 million hectares, but this figure includes plantation forests and degraded patches that provide far less habitat value than primary or secondary natural forest.

For Indian school students — many of whom grow up adjacent to fragmented landscapes without a framework for understanding what they are seeing — this topic offers something rare in science education: a locally observable, globally relevant, and scientifically rich phenomenon. The argument this article makes is straightforward. Habitat fragmentation and its effects on bird diversity should be a cornerstone of field-based science education in Indian schools, because the science is compelling, the local examples are abundant, and the educational design possibilities are genuinely exciting.

II. Understanding Habitat Fragmentation: The Theoretical Foundation

2.1 Island Biogeography and Its Application to Fragmented Landscapes

The theoretical backbone for understanding habitat fragmentation comes from island biogeography, which ecologists Robert MacArthur and Edward O. Wilson established as a framework in their 1967 book. Their core insight was elegant: the number of species an island can support is a predictable function of its size and its distance from the nearest source of colonizing species. The number of species reaches a stable point when extinction rates match immigration rates.

Habitat fragments behave like islands. A forest patch surrounded by agricultural fields is, from the perspective of a forest-interior bird, as isolated as an oceanic island. The "water" it cannot cross is simply a matrix of inhospitable land rather than open sea. The theory predicts — and empirical research has confirmed repeatedly — that smaller and more isolated fragments support fewer species, and that extinction rates in fragments increase as patches shrink. Terborgh (1992), reviewing long-term data from fragmented landscapes across the tropics, found that even large reserves lose interior-dependent species over time if they become isolated.

This theory is accessible to secondary school students with a basic grasp of ecology, and it generates testable predictions that can be investigated in the field. Do forest patches near a school with larger areas hold more bird species than smaller ones? Does the presence of connecting tree lines or hedgerows between patches change what species are present? These are real scientific questions with real answers, and they are the kind that turn students into ecologists.

2.2 Edge Effects and Interior Habitat Loss

When a continuous habitat is fragmented, the proportion of edge — the boundary zone between habitat and the surrounding matrix — increases dramatically relative to interior habitat. Edge environments are ecologically different from interiors. They receive more light, experience greater temperature fluctuation, suffer higher rates of nest predation from generalist predators like crows, mongoose, and rats that thrive at human-modified edges, and are more exposed to invasive species and human disturbance.

Many bird species are edge-sensitive in the negative direction — meaning they avoid edges and require interior conditions to breed successfully. Research on forest birds in the Western Ghats, published in *Biological Conservation* (Ramesh et al., 2010), documented that interior-dependent species like the Malabar trogon and the Sri Lanka frogmouth were absent from small forest fragments even when suitable habitat appeared to be present. The fragments were simply too small to contain enough interior. Every part of them was edge.

As shown in Figure 1, the relationship between fragment size and the proportion of interior versus edge habitat changes nonlinearly, with even modest reductions in patch size producing dramatic losses of core interior area.

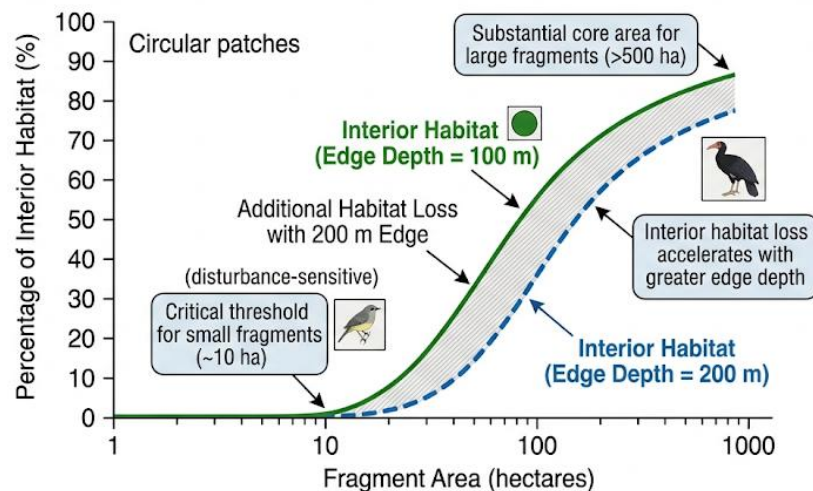


Figure 1: Relationship Between Forest Fragment Size and Available Interior Habitat as a Function of Edge Depth in Tropical Forest Patches

This graph plots fragment area in hectares on the horizontal axis against the percentage of interior habitat (defined as areas more than 100 meters from any edge) on the vertical axis, for circular forest patches ranging from 1 to 1,000 hectares. The curve shows a strongly nonlinear relationship: patches smaller than approximately 10 hectares contain virtually no interior habitat, while patches above 500 hectares retain substantial core areas. A secondary line illustrates how interior habitat loss accelerates when edge depth is increased to 200 meters — a threshold relevant for larger-bodied, disturbance-sensitive species. The figure draws on edge-effect modeling principles described in Laurance et al. (2002) in *Ecological Research*, and

illustrates why small fragments disproportionately lose the bird species most dependent on undisturbed interior conditions.

2.3 Corridor Loss and Population Isolation

Fragmentation does not only reduce patch size — it severs the connections between patches. Wildlife corridors, whether natural (riparian forests, ridgeline vegetation, hedgerow networks) or designed (purpose-built green bridges or stepping-stone habitat patches), allow individuals to move between fragments. This movement is critical for maintaining genetic diversity, allowing recolonization after local extinctions, and enabling range shifts in response to climate change.

Birds are more mobile than many other taxa, so one might assume they handle isolation better. To some extent, this is true for generalist species with high dispersal capacity. But many specialist birds — including undergrowth insectivores, cavity-nesting species, and large raptors — show surprisingly limited movement across open matrix habitats. A study on forest bird movement in fragmented landscapes in southern India found that several understory species essentially never crossed even narrow agricultural gaps between forest patches (Robin et al., 2010, *Journal of the Bombay Natural History Society*). For these species, a 200-meter agricultural field might as well be an ocean.

III. Habitat Fragmentation and Bird Diversity in India: Case Studies

3.1 The Western Ghats: Fragmentation in a Biodiversity Hotspot

The Western Ghats stands as one of eight global biodiversity hotspots which Conservation International has designated as most important for biodiversity preservation. The Western Ghats extends for 1,600 kilometers along India's western coastline which contains a remarkable number of bird species that exist only in this specific region. The area is home to 508 bird species which includes 16 species that exist only in this location and nowhere else on the planet according to Birdlife International 2022. The landscape underwent extensive transformation during the last 100 years because people converted forests into tea coffee and cardamom plantations while building human communities and developing infrastructure.

Research conducted in the Anamalai Hills and Kodagu districts shows that bird populations differ between forest areas that remain intact and plantation areas that contain small forest fragments. Interior-dependent species — including the Indian blue robin, Nilgiri flycatcher, and white-bellied shortwing — consistently populate small forest areas at lower levels while they remain absent from these locations according to Anand et al. (2010) in *Conservation Biology*. The population of plantation birds shows higher levels in fragmented areas which serve as their natural habitat. The overall result is a shift from complex, diverse, endemic-rich communities to simpler, more homogenized assemblages dominated by widespread generalists.

The ecological homogenization of fragmented landscapes represents a primary ecological effect which scientists observe across different habitat fragmentation sites throughout the world. The disappearance of species from habitat fragments leads to ecological disruption because these species fulfill vital functions such as seed dispersal insect predation and pollination. The loss of these services leads to ecosystem degradation which follows their departure.

3.2 Urban Fragmentation in Delhi: Green Spaces and Bird Diversity

The story of fragmentation extends beyond forest and plantation areas. Urban spaces generate their own fragmented green space patterns that include parks and gardens and institutional campuses and tree-lined streets and remaining areas of native plant life which exist within their developed environments. The combination of historical green spaces in Delhi and its rapid urban growth create an interesting urban research case. Research on bird diversity across Delhi's green spaces has shown that species richness correlates with patch size, vegetation structure, and connectivity to other green areas. Bhatt and Bhatt (2018) documented 285 bird species across Delhi's green spaces in their article for the *Journal of Threatened Taxa* but found that small urban parks contained species assemblages which included only a few common species that can withstand disturbances. The Delhi Ridge forest area provides large well-connected patches which support a community that includes raptors and nightjars and forest-associated passerines.

Delhi students and students in other Indian cities can connect their lives to the urban fragmentation situation. Students can observe the school garden and neighborhood park and campus vegetation area to study these locations. The transition of bird diversity from small urban gardens to bigger city parks and to connected wetland corridors can be examined through binoculars and field guides and organized systematic observation.

3.3 The Terai Arc Landscape: Fragmentation and Large-Scale Connectivity

The Terai grasslands and sal forests at the base of the Himalayas in Uttar Pradesh and Uttarakhand support a dramatically different bird community from the Western Ghats — one which contains grassland specialists and large raptors and birds which require the active combination of forest and floodplain and tall grass habitats. The

Bengal florican, lesser florican, and swamp francolin are among the globally threatened bird species that rely on this landscape. All of them are highly sensitive to habitat loss and fragmentation.

The Terai Arc Landscape conservation initiative, developed collaboratively by WWF-India and the Wildlife Institute of India, has identified maintaining connectivity between protected areas — including Dudhwa, Katerniaghat, and Pilibhit tiger reserves — as a priority for both large mammal and bird conservation. Grassland bird populations in the adjacent habitats of these reserves face barriers which result from agricultural and human settlement activities that create fragmentation between the two protected areas. Ben-Ari and Fischman (2021) reviewed landscape connectivity needs for globally threatened birds in South Asia and highlighted the Terai as a landscape where fragmentation-driven population isolation poses immediate extinction risk for grassland specialist species.

IV. School-Based Field Learning: Design Principles and Practical Applications

4.1 Why Field Learning Works

The educational research field has gathered substantial and consistent evidence which demonstrates that direct experience in natural environments provides deeper ecological understanding than classroom instruction can deliver. Students who observe organisms in real habitats, collect real data, and interpret real patterns develop more durable ecological knowledge and stronger pro-environmental attitudes than those who engage with the same content only through text and images.

Chawla (2007), reviewing research on pathways to environmental stewardship, identified repeated positive experiences in natural places during childhood as one of the strongest predictors of adult environmental concern and action. Indian students who spend time in local natural areas — observing, questioning, recording — are not just learning ecology. They are establishing a lifelong relationship with natural places which will drive their conservation efforts. That is worth a great deal.

4.2 Case Study Methodology in the Field

The study of habitat fragmentation needs case studies because researchers can study the phenomenon through two different methods by studying smaller and larger fragments while also studying different areas and their connections. Students can create basic research projects which will evaluate island biogeography theory in their surrounding environment. A practical field protocol might work as follows. The students will choose three to five local green areas which differ in size from school grounds to neighborhood parks and urban forest patches and larger reserves. The team carries out standardized point-count surveys at each patch by standing at predetermined locations during specific time intervals to identify all bird species they observe or hear. The researchers measure patch size and edge length and they assess the vegetation structure. The research shows that multiple field sessions lead to the discovery of two patterns which state that larger patches contain more species and only the biggest patches hold certain species. The patterns which researchers found in this study match the ecological patterns which scientists have documented all over the globe.

The Salim Ali Centre for Ornithology and Natural History (SACON) has developed training materials for school-based bird surveys in India that can support exactly this kind of student fieldwork. Platforms like eBird India allow students to submit their survey data to a national database which makes their observations part of the scientific record.

As shown in Figure 2, a tiered field learning framework can scaffold student skill development from basic identification and observation through comparative habitat analysis to hypothesis-driven ecological investigation.

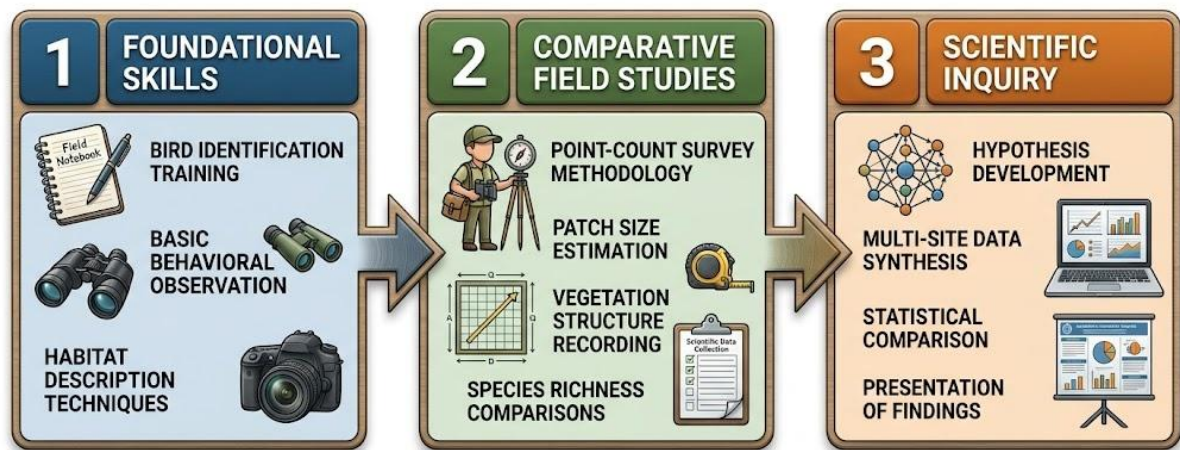


Figure 2: Tiered Field Learning Framework for Habitat Fragmentation Studies in Indian Secondary Schools

The flowchart shows three levels of learning progression which it displays. The street starts with Foundational Skills which train students to identify birds by using field guides and audio recordings and to conduct basic behavioral observations and to describe habitats. The second level of training introduces students to point-count survey methods which include patch size assessment and vegetation structure assessment and site-based species richness measurement. The third level of education includes hypothesis creation which base on island biogeography predictions and cross-site data analysis and species richness comparison between different patch sizes and student research report presentation. The framework aligns with inquiry-based learning competencies outlined in the National Education Policy 2020 (Ministry of Education, Government of India, 2020) and the UNESCO Education for Sustainable Development goals (UNESCO, 2017) and is informed by field survey protocols developed by the Salim Ali Centre for Ornithology and Natural History (SACON, 2019).

4.3 Region-Specific Field Applications Across India

4.4 Citizen Science as a Bridge Between School and Science

The bird citizen science community in India has experienced exceptional growth during the last ten years because of eBird and the dedication of various birding networks including the Indian Bird Conservation Network. The eBird India platform established in 2022 has become a major repository for bird observation data which includes tens of millions of records from thousands of birders throughout India.

Student work gains scientific significance through the connection of their school field learning activities with citizen science platforms. The species lists they submitted to eBird from their local patch project help monitor bird population trends and distribution patterns. A school that conducts regular surveys at the same local locations for multiple years creates a continuous data sequence which shows actual ecological changes that occur in the area because it allows researchers to observe whether specialist species are disappearing from the forest patch and whether birds are returning to restored areas and whether the urban park experiences seasonal shifts in its bird population.

Dasgupta et al. (2022) used eBird data to study bird population changes across Indian environments which they published in Biological Conservation while showing that citizen science programs help monitor areas which professional survey teams cannot access because of the country's vast size. The eBird platform is more than an educational tool for school programs because it provides actual scientific research which adds value to existing scientific knowledge.

V. Conclusion

Habitat fragmentation transforms the bird communities of India through ecological changes that become apparent to observers who examine the regional ecosystems. The scientific study of how fragment size and edge effects and corridor presence and population isolation interact to create species diversity has reached its current state which secondary school students can understand through actual case studies and practical fieldwork.

Indian schools have a genuine opportunity to bring classroom science into the real world of student daily life because NEP 2020 provides experiential and inquiry-based learning methods. The scientific literacy and ecological awareness of young people emerges through case study methods which use local field research and citizen science platforms, such as eBird, to link with national habitat conservation discussions. Young people acquire scientific knowledge about their surroundings which leads them to view their environment as a valuable natural system that needs preservation.

The birds exist. The fragments exist. The scientific framework exists. The educational system needs to establish links between these three elements.

References

- [1]. Anand, M. O., Krishnaswamy, J., Kumar, A., & Bhatt, S. (2010). Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: Remnant forests matter. *Biological Conservation*, 143(10), 2363–2374. <https://doi.org/10.1016/j.biocon.2010.01.013>
- [2]. Ben-Ari, M., & Fischman, E. (2021). Landscape connectivity needs of globally threatened birds in South Asian grassland and forest mosaics. *Bird Conservation International*, 31(2), 289–305. <https://doi.org/10.1017/S0959270920000143>
- [3]. Bhatt, D., & Bhatt, A. (2018). Avian diversity and distribution in urban green spaces of Delhi. *Journal of Threatened Taxa*, 10(10), 12347–12362. <https://doi.org/10.11609/jott.3941.10.10.12347-12362>
- [4]. BirdLife International. (2022). *State of the world's birds: Insights and solutions for the biodiversity crisis*. BirdLife International. <https://www.birdlife.org/state-of-the-worlds-birds/>
- [5]. Chawla, L. (2007). Childhood experiences associated with care for the natural world: A theoretical framework for empirical results. *Children, Youth and Environments*, 17(4), 144–170. <https://doi.org/10.7721/chilyoutenvi.17.4.0144>
- [6]. Dasgupta, S., Bhatt, S., & Srinivasan, U. (2022). Using citizen science data to assess bird population trends across Indian landscapes. *Biological Conservation*, 265, 109408. <https://doi.org/10.1016/j.biocon.2021.109408>
- [7]. Forest Survey of India. (2021). *India state of forest report 2021* (Vol. I). Ministry of Environment, Forest and Climate Change, Government of India. <https://fsi.nic.in/forest-report-2021>
- [8]. Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., Gascon, C., Bierregaard, R. O., Laurance, S. G., & Sampaio, E. (2002). Ecosystem decay of Amazonian forest fragments: A 22-year investigation. *Conservation Biology*, 16(3), 605–618. <https://doi.org/10.1046/j.1523-1739.2002.01025.x>
- [9]. MacArthur, R. H., & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton University Press.
- [10]. Ministry of Education, Government of India. (2020). *National education policy 2020*. Government of India. https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf
- [11]. Praveen, J., Jayapal, R., & Pittie, A. (2016). A checklist of the birds of India. *Indian Birds*, 11(5–6), 113–172. [https://www.indianbirds.in/pdfs/IB11\(5%266\).pdf](https://www.indianbirds.in/pdfs/IB11(5%266).pdf)
- [12]. Ramesh, B. R., Venugopal, P. D., Pélissier, R., Patil, S. V., Bhatt, S., & Couteron, P. (2010). Mesoscale patterns in the diversity and structure of the Western Ghats endemic tree flora of the Karnataka biodiversity hotspot. *Biological Conservation*, 143(4), 1093–1102. <https://doi.org/10.1016/j.biocon.2010.02.006>
- [13]. Robin, V. V., Sinha, A., & Ramakrishnan, U. (2010). Ancient geographical gaps and paleo-climate shape the phylogeography of an endemic bird in the sky islands of an inland mountain range. *PLOS ONE*, 5(10), e13321. <https://doi.org/10.1371/journal.pone.0013321>
- [14]. Salim Ali Centre for Ornithology and Natural History. (2019). *Field survey protocols for school bird monitoring programs in India*. SACON Technical Report. <https://sacon.in>
- [15]. Terborgh, J. (1992). *Diversity and the tropical rainforest*. Scientific American Library.
- [16]. United Nations Educational, Scientific and Cultural Organization. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000247444>
- [17]. Wildlife Institute of India & WWF-India. (2019). *Terai arc landscape conservation strategy: Connectivity, corridors, and species recovery*. WII Technical Report. <https://www.wii.gov.in>
- [18]. Wilson, E. O. (2016). *Half-earth: Our planet's fight for life*. Liveright Publishing.
- [19]. WWF-India. (2020). *Living planet report India: Measuring India's ecological footprint and biodiversity trends*. WWF-India. <https://www.wwfindia.org>