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# Impact of Climate Change and Habitat Fragmentation on the Biodiversity of Chhindwara District, Madhya Pradesh: A Comprehensive Review

Dr. Ritu Sharma

*Assistant Professor, Department of Zoology,  
Pradhan Mantri College of Excellence, Government Autonomous Post Graduate College,  
Chhindwara, M.P., India*

**Abstract**— The Chhindwara district, located in the ecologically sensitive Satpura range of Madhya Pradesh, serves as an important pathway for Central Indian biodiversity. In recent years, the area has seen significant ecological changes due to climate change and habitat fragmentation. This review paper gathers existing research to assess the combined effects of rising average temperatures, unpredictable rainfall, and shifts in land use on the district's diverse flora and fauna. It highlights the fragmentation caused by mining, urban growth, and infrastructure development, which have disrupted natural pathways and increased edge effects in both protected and unprotected areas. The study emphasises the vulnerability of endemic species, particularly in unique microhabitats such as Patalkot, and notes changes in the behaviours of local insect and bird populations. By identifying key knowledge gaps, this study urges combined conservation efforts and ongoing ecological monitoring to address biodiversity loss in this changing landscape.

**Keywords**— Biodiversity, Chhindwara, Climate Change, Habitat Fragmentation, Satpura Range, Conservation.

## I. INTRODUCTION

### A. Background and Geographical Context

The Chhindwara district lies in the centre of the Satpura-Maikal landscape in Madhya Pradesh. It serves as an important ecological transition zone in Central India. The district is located between 21°28' and 22°49' North latitude and 78°10' and 79°24' East longitude. It features a diverse range of landscapes, from the high plateaus of Tamia to the deep, secluded valley of Patalkot. After the administrative reorganisation in 2023, the district covers about 10,293 km<sup>2</sup> (Government of Madhya Pradesh, 2023). The area is known for its "Chhind" (wild date palm) trees, which give the district its name.

The rugged terrain of the Satpura Plateau includes a unique mix of tropical dry deciduous forests and moist peninsular teak forests (Champion & Seth, 1968).

### B. Ecological Significance

The ecological importance of Chhindwara serves as a vital wildlife corridor within the broader Central Indian Highlands, acting as a bridge for species dispersal between major National Parks and Tiger Reserves (Qureshi et al., 2014; Banerjee et al., 2020). These forests are a repository of immense biological wealth, providing a variety of microhabitats, evidenced by new botanical records such as *Ficus capulata* in the Satpura region (Bawistale, 2012), that support a rich diversity of flora, including a high documented diversity of Pteridophytes that thrive in the district's moist niches (Thakur & Baghel, 2021; Meshram & Khobragade, 2021; Jha et al., 2015). Beyond megafauna, the district hosts highly specialised assemblages of Odonata (dragonflies) and Coleoptera (beetles) (Dass & Sharma, 2024). The abundance of these aquatic and terrestrial invertebrates serves as a critical bio-indicator of the health of the local ecosystem and its perennial water bodies, reflecting the overall integrity of the Satpura-Maikal corridor (Tiple et al., 2013).

### C. Problem Statement: The Synergy of Climate and Fragmentation

Despite its biological richness, Chhindwara is currently facing a dual-threat scenario where environmental stressors act in damaging synergy (Kumari et al., 2023). First, Anthropogenic Climate Change has disrupted the historical climatic stability of the plateau. Meteorological records indicate a steady rise in mean annual temperatures—frequently peaking near 45°C—alongside increasingly erratic monsoon cycles (IPCC, 2023; IMD, 2024).



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These changes directly impact the phenology of local species, leading to altered emergence patterns in insects and threatening the foundational levels of the food web (Hald-Mortensen, 2022).

Second, the physical landscape is undergoing severe habitat fragmentation. The expansion of linear infrastructure (such as NH-47), intensified coal mining operations in the Pench-Kanhan belt, and urban sprawl have carved continuous forest cover into isolated "habitat islands" (Dutta et al., 2016). This fragmentation heightens the edge effect, making interior forest species more vulnerable to invasive flora such as *Lantana camara* and exacerbating human-wildlife conflict.

### D. Scope and Objectives of the Review

While individual studies exist on the broader flora and fauna of Madhya Pradesh, there remains a significant lack of integrated research focusing specifically on how climate variability and physical fragmentation interact within the specific context of Chhindwara. This review paper seeks to address this gap by synthesising research and ecological data documented between 1968 and 2026. The primary objectives are to:

- Document the recorded shifts in local biodiversity over the last three decades.
- Analyse the primary drivers of habitat fragmentation and land-use change in the region.
- Identify critical "Knowledge Gaps" to provide a framework for sustainable conservation strategies tailored to the unique Satpura landscape.

## II. METHODOLOGY

### A. Search Strategy and Data Sources

A systematic literature search was conducted to identify peer-reviewed articles, technical reports, and academic theses published between the year of 1968 and 2026. The primary databases utilised for this search included Google Scholar, ScienceDirect, ResearchGate, and the Web of Science. To ensure regional accuracy, secondary data was also sourced from the official records of the State Forest Research Institute (SFRI), Jabalpur, and the District Gazette of Chhindwara.

To narrow the search from over 6,000 preliminary results to a relevant subset, specific Boolean operators and keyword strings were employed, including:

"Chhindwara" AND "Biodiversity"

"Satpura Range" AND "Habitat Fragmentation"

"Central India" AND "Climate Change" AND "Species Diversity"

"Odonata" OR "Coleoptera" AND "Madhya Pradesh"

### B. Inclusion and Exclusion Criteria

To maintain high academic standards, strict criteria were applied to the selection of literature:

**Inclusion Criteria:** Studies focusing specifically on the Chhindwara district or the broader Satpura-Maikal landscape; research documenting quantitative changes in flora and fauna; and papers discussing climate trends in Central India.

**Exclusion Criteria:** Non-peer-reviewed blog posts; studies conducted before the year 1965 (unless required for historical baseline data); and medical or unrelated industrial research mentioning the district.

### C. Data Extraction and Synthesis

Following the initial screening of titles and abstracts, approximately 80 full-text articles were selected for detailed review. Data extraction focused on three primary variables:

**Climatic Variables:** Changes in temperature and precipitation.

**Landscape Variables:** Rate of forest cover loss and infrastructure expansion.

**Biological Variables:** Species richness, abundance, and phenological shifts in bio-indicators like dragonflies and beetles.

The synthesised data were then categorised into thematic sections to evaluate the synergistic effects of environmental stressors on the district's biodiversity.

Reference management and citation tracking were performed using Zotero 7.0.

## III Climate Change Trends in the Satpura Plateau

### A. Temperature and Precipitation Analysis

The Chhindwara plateau has witnessed a statistically significant deviation from its historical climatic baseline, posing a severe threat to the livelihood vulnerability of local tribal communities (Kumar & Mohanasundari, 2023).



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Analysis of meteorological data from the Indian Meteorological Department (IMD) for the period 2000–2026 reveals a warming trend, with mean annual maximum temperatures increasing by approximately 0.5°C to 0.8°C. The region now frequently experiences "heatwave" conditions in the pre-monsoon months (April–May), with peak temperatures consistently hitting the 43°C to 45°C range.

Precipitation patterns have similarly become erratic. While the total volume of the South-West Monsoon remains somewhat stable, the temporal distribution has shifted. The district now experiences shorter, high-intensity rainfall events followed by prolonged dry spells. These "flash" events lead to rapid runoff, reducing the groundwater recharge capacity of the Satpura aquifers and causing seasonal stress to the district's perennial streams and wetlands.

### *B. Impact on Phenology*

These climatic shifts have triggered profound phenological changes in the local biota. Phenology—the study of periodic biological phenomena such as flowering, breeding, and migration—is highly sensitive to thermal cues.

**Floral Phenology:** Studies in the Tamia and Patalkot regions indicate that several indigenous tree species, including *Madhuca longifolia* (Mahua) and *Tectona grandis* (Teak), are exhibiting earlier flowering cycles.

**Faunal Response:** For ectothermic organisms like Odonata (dragonflies) and Coleoptera (beetles), rising temperatures accelerate larval development but often result in smaller adult body sizes and reduced fecundity. The "mismatch" between the emergence of predatory insects and the availability of their prey is an emerging concern for the district's ecological stability.

### *C. Micro-climatic Shifts in Specialised Ecosystems*

The most alarming impact of climate change in Chhindwara is observed in its specialised micro-habitats. The Patalkot Valley, a deep horseshoe-shaped canyon, has historically maintained a micro-climate where ecotourism and tribal livelihood are intrinsically linked to the valley's health and the preservation of unique medicinal plant diversity by local tribes (Parte & Parte, 2022; Yadav et al., 2024). However, as global temperatures rise, the "buffer" effect of the valley is weakening.

The increasing dryness is leading to a decline in hygrophilous (moisture-loving) species, including rare ferns and medicinal bryophytes, which are being replaced by more drought-tolerant, invasive vegetation.

## IV DRIVERS OF HABITAT FRAGMENTATION

### *A. Infrastructure and Urban Expansion*

The rapid development of linear infrastructure is one of the primary drivers of fragmentation in Chhindwara. The expansion of National Highways, particularly the NH-47 (Nagpur-Chhindwara-Itarsi) and state highways connecting to Amarwara and Sausar, has bisected previously contiguous forest patches. These roads act as 'hard barriers' for ground-dwelling fauna, including reptiles and small mammals, whose ethnozoological significance and traditional use by local tribes are vital components of the region's cultural and biological heritage (Bagde & Jain, 2013; Bagde & Jain, 2015; WII, 2015). Furthermore, the expansion of Chhindwara city and the development of large-scale urban infrastructure, such as sewerage networks, have altered the local land-use patterns (MPUDC Report, 2020).

### *B. Mining and Industrial Activity*

Chhindwara is geographically situated over the rich coal-bearing strata of the Pench-Kanhan Valley. The proliferation of both open-cast and underground coal mines, particularly in the Parasia region, has significantly altered the forest ecosystem and its structural integrity (Kumar & Rathoure, 2015). Mining activities lead to:

**Direct Habitat Loss:** Clearing of vast tracts of forest cover for excavation.

**Geological Disruption:** Changes in the water table and soil composition that affect the survival of native vegetation.

**Noise and Light Pollution:** Industrial operations disrupt the nocturnal behaviours of local fauna, particularly owls and nocturnal beetles, creating a "barrier effect" even where physical forest cover remains.

### *C. Agricultural Encroachment*

As the human population in the district grows, there is an increasing pressure to convert forest fringes into agricultural land. This "nibbling" effect at the forest edges reduces the core forest area.



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In many parts of the district, the transition from mixed tropical forests to monocultures (such as orange orchards in the southern tehsils or maize in the central plateau) has stripped the land of its natural undergrowth. This loss of diverse shrubs and grasses is particularly detrimental to Odonata and Coleoptera, which rely on specific host plants and undisturbed soil for different stages of their life cycles (Deokar & Meshram, 2023).

### V CONSEQUENCES FOR BIODIVERSITY

#### A. Impact on Floral Diversity

The fragmentation of the Chhindwara forests has resulted in a pronounced "edge effect," characterised by increased exposure of the forest perimeter to intense sunlight and reduced humidity. This environmental alteration has facilitated the incursion of exotic weeds, posing a threat to the diverse indigenous plant species that have historically characterised the district's flora (Shrivastava, 2019). These invasive species outcompete native medicinal plants, leading to a reduction in the availability of traditional healing resources, even within the documented medicinal diversity of urban Chhindwara (Bawistale et al., 2021; Dar et al., 2023). In ecologically sensitive regions such as Patalkot, the isolation of plant populations restricts genetic exchange, rendering rare species of bryophytes and pteridophytes more susceptible to local extinction.

#### B. Impact on Faunal Assemblages

1) *Invertebrates*: Odonata, Coleoptera, and Butterfly fauna are highly sensitive to micro-climatic fluctuations, with their abundance serving as a critical indicator of habitat health (Bhowate & Kumar, 2020). For insects, fragmentation often means the loss of specialised breeding sites.

Odonata: Dragonflies and damselflies are highly dependent on clean, slow-moving water bodies. Fragmentation caused by mining and road siltation often leads to the drying up or pollution of these perennial streams.

Coleoptera: Beetles, especially wood-boring and dung beetles, require specific forest structures. The loss of old-growth trees and the reduction in large mammal movement (due to roads) have led to a noticeable decline in the diversity of these essential decomposers in the district.

#### 2) *Vertebrates*: Avian and Mammalian Disruption

Avian diversity in Chhindwara, particularly within the West Chhindwara region, includes a wide array of species whose conservation is critical in the face of habitat loss (Bagde, 2024 a), including reptiles and mammals, whose populations are increasingly susceptible to eco-climatic changes and anthropogenic disturbances within the Pench landscape (Sigotiya and Tiwari, 2018). Notably, there have been rare sightings of the Critically Endangered Forest Owlet. However, there is a discernible shift towards 'generalist' species, such as crows and mynas, which thrive in fragmented landscapes, while 'specialist' forest birds, including woodpeckers and flycatchers, are experiencing a decline (Sharma, 2024; Mehta et al., 2008). For larger mammals, habitat fragmentation exacerbates the risk of roadkill and increases the frequency of Human-Wildlife Conflict, as species such as leopards and wild boars are compelled to traverse agricultural fields to move between forest patches (Status of Leopard in India, 2022).

### VI. DISCUSSION

#### A. Synergistic Effects of Environmental Stressors

A critical finding of this review is that climate change and habitat fragmentation do not act as isolated variables in Chhindwara; instead, they exert a synergistic pressure on the ecosystem. Fragmentation reduces the "thermal buffer" of the forest. When a continuous forest is broken into smaller patches, the interior humidity drops and the temperature rises. This "edge effect" accelerates the impact of global warming, making these forest islands even hotter and drier than they would be if they were part of a continuous canopy. For moisture-dependent species in the Satpura range, this dual pressure creates a "trap" where they cannot move to cooler areas because their paths are blocked by roads or mines.

#### B. Human-Wildlife Conflict and Landscape Connectivity

The data indicate a clear correlation between increased fragmentation in the Pench-Kanhan belt and the rise in human-wildlife encounters. As forests become "islands," large mammals and even avian species are forced to move through agricultural land and human settlements to find resources (Status of Leopard in India, 2022). This lack of landscape connectivity is not just a conservation issue but a social one, leading to crop raiding and safety concerns for local communities.



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"Protecting 'corridors' and managing the high faunal diversity of the West Division are identified as the most urgent requirements for the district's management plan (Bagde, 2024b; Rathore et al., 2012).

### *C. Evaluation of Current Conservation Policies*

While the establishment of protected areas and Eco-sensitive zones around Pench and Tamia has provided some refuge, the "non-protected" forests of Chhindwara (which make up a large portion of the district) remain vulnerable (Khare, 2021). Current policies often focus on "afforestation" (planting trees), but this review suggests that "restoration" of complex ecosystems is more vital. Planting monocultures of Eucalyptus or Acacia does not provide the specialised habitat required by the district's Odonata or Coleoptera assemblages, which need diverse native undergrowth and clean seasonal streams.

### VII KNOWLEDGE GAPS AND FUTURE RESEARCH DIRECTIONS

Despite the wealth of general biodiversity data, several "Knowledge Gaps" have been identified:

**Taxonomic Neglect:** While large mammals and birds are well-documented, there is a lack of long-term monitoring for Invertebrates (Insects) and Soil Microbes, which are the true indicators of climate resilience (Bheemalingappa et al., 2023), although general plant diversity has been extensively documented in recent years (Agriworld, 2021).

**Geospatial Mapping:** There is an urgent need for high-resolution GIS (Geographic Information System) mapping to identify "micro-corridors" that insects and small reptiles use to navigate the fragmented landscape of Chhindwara (Khan et al., 2022).

**Citizen Science:** Future research should involve "Citizen Science" initiatives, in which students and residents contribute to data collection via mobile platforms, helping track seasonal changes in flowering or insect emergence across the district's diverse altitudes.

### VIII Conclusion and Policy Recommendations

#### *A. Summary of Findings*

This review underscores that Chhindwara District stands at a critical ecological crossroads. The synthesis of data from 1968 to 2026 reveals that the synergy between a warming Satpura climate and a physically fragmented landscape is fundamentally altering the region's biological fabric.

The decline of sensitive bio-indicators, such as Odonata and Coleoptera, and the shrinking micro-climatic refugia of the Patalkot Valley are early warning signs of a broader ecosystem collapse. While the district maintains significant forest cover, its increasing "insularity" threatens the long-term survival of both floral and faunal assemblages.

#### *B. Strategic Recommendations*

To mitigate these impacts, the following policy shifts are recommended:

**Establishment of "Micro-Corridors":** Conservation efforts must move beyond protected areas to identify and protect small "stepping-stone" habitats that allow for the migration of insects and small vertebrates across agricultural and industrial zones.

**Climate-Resilient Afforestation:** "Reforestation projects should prioritise a diverse mix of native species, guided by local phytosociological studies to ensure effective restoration of tree diversity (Haque & Singh, 2017), particularly those that provide nectar and host sites for specialised invertebrates, rather than monoculture plantations.

**Integrated Environmental Impact Assessments (EIA):** Future mining and infrastructure projects in the Pench-Kanhan belt must account for the cumulative impact of fragmentation on landscape connectivity, rather than evaluating individual project sites in isolation.

**Academic-Government Partnerships:** utilising the research capacity of local institutions, such as the Pradhan Mantri College of Excellence and the Forest Research Centre for Skill Development (Khobragade, 2023), to create a "District Biodiversity Observatory" for real-time monitoring of phenological shifts.

In conclusion, the preservation of Chhindwara's biodiversity requires a transition from traditional "fortress conservation" to a landscape-level management approach that recognises the interdependence of climate stability and habitat continuity.

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