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Biodiversity conservation in the Melghat landscape, Maharashtra, India: Habitat connectivity, anthropogenic pressures and research priorities

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Abstract
The Melghat landscape of northern Maharashtra forms part of the Satpura–Melghat system of the Central Indian landscape and contains dry deciduous forests, valleys, ridges, grasslands, streams and human-used buffer areas. Its conservation importance extends beyond the boundaries of a single protected area because wildlife persistence depends on habitat quality, dispersal opportunities and ecological processes operating across the wider landscape. Melghat Tiger Reserve includes Gugamal National Park and the Melghat, Wan, Ambabarwa and Narnala wildlife sanctuaries, together with buffer areas. Published tiger assessments and landscape-connectivity research identify the wider Satpura–Melghat region as important for dispersal and long-term conservation (Jhala *et al*., 2014; Sharma *et al*., 2013) [2, 6]. This review synthesizes scientific literature and publicly available conservation information published up to 2022 to examine landscape connectivity, habitat structure, human pressures and research priorities. Key issues include forest-cover change, road and linear-infrastructure impacts, resource use in buffer areas, human–wildlife interactions, habitat degradation and the need to reconcile conservation with local livelihoods. Available sources identify these as concerns requiring site-specific assessment; general threats should not be represented as measured impacts at every site. A landscape-scale programme should combine satellite-based land-cover analysis, camera-trap and sign surveys, occupancy modelling, genetic sampling where feasible, road-risk mapping and participatory monitoring. Conservation priorities include protecting existing forest links, restoring degraded patches where ecological evidence supports restoration, applying wildlife-sensitive infrastructure design, maintaining riparian and valley habitats, and strengthening community partnerships. Melghat should be managed as a connected socio-ecological landscape rather than as an isolated tiger reserve, while future research must quantify connectivity and pressures with transparent, repeatable methods.

Keywords: Melghat, biodiversity conservation, habitat connectivity, tiger landscape, Satpura, land-use change, linear infrastructure, human–wildlife coexistence, Maharashtra

Introduction

Biodiversity conservation in large forest landscapes requires attention not only to the protection of individual species or protected areas but also to the spatial relationships among habitats, populations and human land uses. Animals move to find food, mates, seasonal resources and refuge; plants and many animals depend on dispersal processes that operate beyond reserve boundaries. When natural habitat is divided by roads, settlements, intensive agriculture or other land uses, movement may become more difficult and the risk of mortality or conflict may increase. Landscape ecology therefore treats habitat configuration, connectivity and matrix quality as important complements to habitat area (Bennett, 2003; Taylor *et al*., 1993) [1, 7].

Melghat, located in the Satpura hill ranges of Maharashtra, is an important forest landscape in the Central Indian tiger conservation system. Earlier tiger assessments and landscape-genetic research place Melghat within a wider network of forested and partly modified areas extending towards Madhya Pradesh and other parts of central India (Jhala *et al*., 2014; Sharma *et al*., 2013) [2, 6]. These relationships make habitat connectivity a central conservation issue rather than a secondary management consideration.

Melghat's conservation future is also inseparable from the needs and rights of communities living in and around the reserve. Forest-dependent livelihoods, access to water and forest products, agricultural development, roads, tourism and human–wildlife interactions all shape how land is used. Conservation measures that ignore these relationships may be difficult to implement or may transfer costs to local people. Conversely, participatory planning and ecologically compatible development can help maintain habitat and reduce conflict when designed around local evidence and community priorities (Karanth & Nepal, 2012) [3].

This review examines biodiversity conservation in the Melghat landscape through three connected themes: the ecological role of habitat connectivity, the principal anthropogenic pressures that require management, and the research approaches needed to support evidence-based decisions. It is a narrative synthesis of published scientific work and official documents, not a new field survey or a quantitative systematic review.

Review scope and evidence approach

The review gives priority to peer-reviewed studies and publicly available conservation sources that address Melghat or the wider Central Indian tiger landscape. Core sources include national tiger assessment reports, research

on tiger habitat linkages, and established landscape-ecology literature. These sources are used to explain connectivity and fragmentation mechanisms; they do not replace site-specific field validation.

Search concepts appropriate for updating this review include "Melghat Tiger Reserve connectivity", "Melghat buffer zone mammals", "Satpura–Melghat tiger corridor", "Melghat forest cover change", "linear infrastructure wildlife Maharashtra", "human–wildlife conflict Melghat", and "community conservation Melghat". A journal submission should state the databases, search dates, full search strings, inclusion criteria and screening process if a systematic-review label is intended. The present manuscript should be described as a critical narrative review unless that formal protocol is completed.

Evidence is interpreted at the scale at which it was collected. A finding from the Melghat buffer zone is not automatically generalized to the entire reserve, and a modelled corridor between distant reserves is not treated as proof that every segment is currently functional. Similarly, management-plan statements are cited as official assessments or reported concerns, not as independent experimental confirmation of causality.

Landscape setting and conservation significance

Earlier national tiger assessments place Melghat within the Central Indian tiger landscape and identify the reserve as part of a wider ecological setting that includes protected areas and surrounding buffer lands (Jhala *et al*., 2014 [2]; Wildlife Institute of India & National Tiger Conservation Authority, 2014) [2]. Area figures can vary by source and reporting period, so any numerical statement about reserve or buffer extent should identify the source and year. This review avoids presenting unverified area figures as current measurements.

The landscape includes dry deciduous forest, hill slopes, valleys, grasslands, streams and areas of human use. Elevation and topography influence local climate, vegetation and water availability. Forested ridges and valleys can provide cover and movement routes, while streams and riparian vegetation may serve as local ecological corridors. However, connectivity is not established by vegetation continuity alone: the suitability of a route depends on species, disturbance, prey or food availability, barriers, mortality risk and the degree to which animals can cross the surrounding matrix.

The reserve is important for large carnivores, prey species and a broad range of other organisms. Earlier national assessment reports provide a basis for understanding its role in tiger conservation, while a complete biodiversity inventory requires taxon-specific surveys with documented methods and dates (Wildlife Institute of India & National Tiger Conservation Authority, 2014) [2]. The wider conservation value of Melghat includes ecosystem services such as catchment protection, soil retention and water supply, as well as cultural and livelihood values for local communities.

Habitat connectivity: concepts and evidence

1. Structural and functional connectivity

Structural connectivity describes the physical arrangement of habitat patches and the presence of intervening vegetation, whereas functional connectivity describes whether organisms can actually move between patches. The two may diverge. A narrow-wooded strip may look connected on a satellite image but be avoided by a large mammal because of traffic, settlements, human activity or insufficient cover. Conversely, some species may cross a matrix that appears fragmented to a human observer. Connectivity assessments should therefore combine spatial data with evidence of movement, occupancy, mortality or genetic exchange (Taylor *et al*., 1993; Bennett, 2003) [1, 7].

For Melghat, connectivity is relevant at multiple scales. At the local scale, animals move among valleys, water sources, feeding areas and forest blocks. At the reserve scale, movement between core and buffer areas may support dispersal and access to seasonal resources. At the regional scale, links between Melghat and the wider Satpura system may support demographic exchange and long-term population viability. A conservation plan should distinguish these scales rather than use the word "corridor" for every strip of forest.

2. Regional linkages and tiger conservation

Landscape-genetic research in central India has identified potential connectivity among several tiger reserves, including linkages involving Melghat and other protected areas. Such studies show how least-cost paths, circuit-theory models and genetic data can be used to evaluate alternative movement routes (Jhala *et al*., 2014; Sharma *et al*., 2013) [2, 6]. These outputs are analytical models that require ground validation and should be interpreted with their assumptions and data limitations in mind. A modelled corridor indicates a candidate area for field investigation, not a guarantee of regular animal movement.

Research on tiger populations and landscape connectivity in Central India emphasizes the potential importance of links among protected areas and the need to assess dispersal and gene flow with appropriate spatial and genetic evidence (Jhala *et al*., 2014; Sharma *et al*., 2013) [2, 6]. This supports a management approach that considers habitat quality beyond formal boundaries and coordinates planning with neighbouring forest divisions and jurisdictions.

3. Buffer areas and habitat mosaics

Buffer landscapes contain a mixture of forests, agricultural land, villages, roads and other uses. They may provide dispersal opportunities, but their effectiveness depends on habitat quality, species-specific requirements and the level of disturbance. Management and research should therefore avoid assuming that all mammals respond identically to the same landscape features and should evaluate connectivity with field observations appropriate to each target species.

Management should therefore avoid a single universal connectivity metric. Tiger movement, dispersal of smaller carnivores, movement of ungulates and the requirements of forest-dependent birds or invertebrates may respond differently to vegetation structure and human disturbance. A multi-taxon assessment can reveal whether a proposed intervention benefits one group while disadvantaging another.

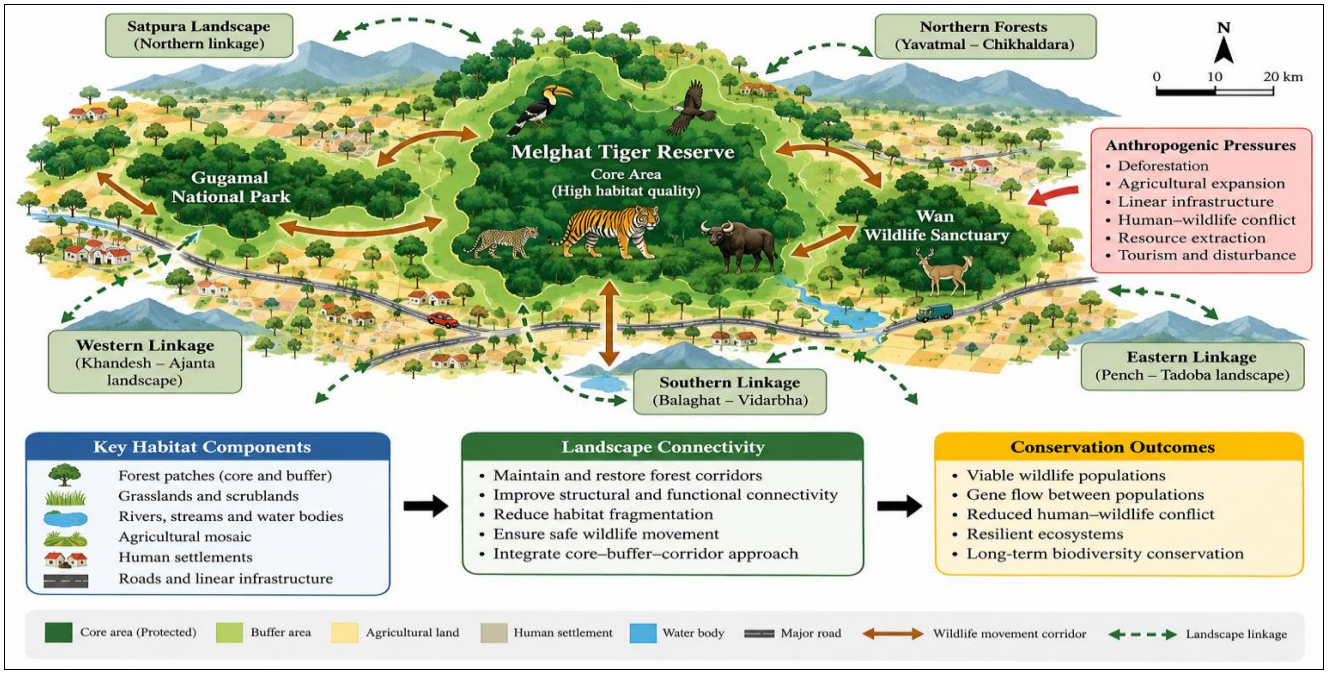


Fig 1: Conceptual framework for landscape connectivity in the meight landscape, meharashtra, India

Anthropogenic pressures

1. Forest-cover change and habitat degradation

Forest loss and degradation can reduce habitat area, alter vegetation structure and increase edge effects. The extent, location and causes of change in Melghat should be established using dated land-cover data, comparable satellite imagery and field validation. Such analysis should identify where loss occurred, what land uses replaced forest and whether the change affected potential movement areas. Numerical claims about forest-cover loss should include a clearly stated assessment period and source.

Remote-sensing analysis can distinguish changes in canopy cover, fragmentation, fire scars and land conversion, but classifications require validation and careful selection of dates. Seasonal leaf loss in dry deciduous forest may be misinterpreted as degradation if images are not seasonally comparable. A robust analysis should use consistent definitions, multiple years, field checks and uncertainty estimates. Forest-cover change should also be distinguished from forest degradation, because a site can retain tree cover while losing understory structure, large trees or ecological function.

2. Roads and linear infrastructure

Roads, power lines, canals, railways and other linear infrastructure can affect wildlife through direct mortality, barriers to movement, noise, light and increased human access. Their effects depend on traffic volume, road width, speed, surrounding cover, species behaviour and the placement of crossing structures. The National Tiger Conservation Authority highlights the need to protect areas linking tiger reserves and refers to eco-friendly measures for mitigating linear-infrastructure impacts (NTCA, n.d.).

For Melghat, road-risk assessment should identify locations where roads intersect likely movement routes, stream crossings, ridgelines and valley corridors. Camera traps, track surveys, systematic carcass searches and traffic data can help distinguish perceived risk from measured mortality. Mitigation may include speed management, signage, crossing structures, fencing designed to guide animals safely, and restrictions on disruptive activity in sensitive periods. Each measure should be evaluated after implementation rather than assumed effective by design.

3. Resource extraction and livelihood dependence

Communities living in forest landscapes may depend on fuelwood, fodder, non-timber forest products, grazing, water and other resources. Resource use should not be described uniformly as destructive: its ecological effects depend on intensity, location, season, species harvested and local management arrangements. Research should evaluate both biodiversity outcomes and the distribution of costs and benefits to local communities.

Conservation strategies should identify which uses are sustainable, which require regulation, and which alternatives are feasible and acceptable. Participatory resource mapping, village-level monitoring and co-designed restoration can improve legitimacy and compliance. Restrictions imposed without transparent consultation may increase hardship or displace resource use to other areas. A socio-ecological approach should therefore evaluate both biodiversity outcomes and distribution of costs and benefits.

4. Human–wildlife interactions

As wildlife moves through buffer areas and human-used landscapes, encounters with livestock, crops, settlements and transport routes may occur. The severity of conflict varies by species, season, local husbandry, crop type and access to rapid compensation or support. The presence of a protected area does not itself establish that conflict is increasing; claims of trends require dated records with consistent definitions.

A systematic conflict database should record location, species, event type, season, verified losses, response time and mitigation action. Community interviews can provide contextual information but should be analysed alongside official records and field verification. Practical measures may include improved livestock protection, timely response systems, targeted deterrents, safe waste management and transparent compensation processes. The appropriate

intervention must be tailored to the species and local conditions.

5. Fire, grazing and vegetation change

Fire and grazing are ecologically complex in dry deciduous forests and adjoining grasslands. Some disturbance regimes can maintain open habitats, while severe or repeated fires and excessive grazing can prevent regeneration, alter understory composition or reduce cover. It is therefore inappropriate to classify every fire or grazing event as uniformly harmful. Monitoring should record fire frequency, season, intensity where feasible, vegetation recovery and wildlife responses, and should distinguish natural or managed open habitats from degraded forest.

6. Tourism and settlement expansion

Nature-based tourism can support livelihoods and conservation awareness, but unmanaged visitor traffic, noise, waste, off-road travel and disturbance at sensitive sites can reduce habitat quality. Settlement growth and road improvements may also increase access to previously less disturbed areas. Visitor planning should use zoning, seasonal restrictions where justified, waste management, community participation and monitoring of ecological indicators. Tourism benefits should be assessed alongside its environmental footprint and the distribution of income.

Biodiversity beyond flagship mammals

Although Melghat is strongly associated with tiger conservation, the landscape supports multiple taxa and ecological processes. Conservation planning focused only on large carnivores' risks overlooking species with different habitat requirements, including forest understory birds, amphibians associated with streams, pollinators, soil fauna and plants restricted to particular rock, slope or moisture conditions. Multi-taxon surveys are needed to document these groups using appropriate sampling methods.

A multi-taxon approach can reveal whether forest restoration or corridor protection benefits broader biodiversity. Birds and butterflies may provide useful indicators of vegetation structure and seasonal resources, while amphibians and aquatic invertebrates may be sensitive to stream condition. These groups should not be treated as interchangeable proxies; each requires appropriate sampling and interpretation. A baseline inventory should document taxonomy, sampling effort, season and evidence quality so that future comparisons remain meaningful.

Biodiversity inventories should also distinguish presence records from abundance estimates and confirmed breeding from transient occurrence. Opportunistic records can extend known distributions, but uneven observer effort and differences in detectability complicate comparisons. Standardized field surveys, voucher records where appropriate, georeferenced photographs or audio, and transparent data curation are important for a reliable regional biodiversity evidence base.

Conservation planning and governance

The legal and management framework for tiger reserves recognizes the importance of ecological land use in areas linking reserves and of buffer areas where wildlife conservation and human livelihoods must be considered together. The National Tiger Conservation Authority describes corridor areas as relevant to dispersal and identifies the need to manage land-use change in ecologically important areas (NTCA, n.d.). For Melghat, these principles require coordination among forest divisions, district administration, infrastructure agencies, village institutions and neighbouring jurisdictions.

Conservation planning should separate actions within core habitat from those in buffer and corridor areas. Core management may emphasize disturbance control, protection of breeding and resting habitat, prey availability and enforcement against illegal activities. Buffer management requires a broader set of tools, including community-led resource governance, compatible agriculture, conflict mitigation and carefully planned infrastructure. Corridor landscapes may require negotiated land-use measures, restoration of selected bottlenecks and monitoring of animal movement.

Community participation is not simply an outreach component; it is part of the implementation architecture. Local knowledge can help identify seasonal wildlife movement, water availability, fire history and changes in resource use. Co-management arrangements should be transparent about rights, responsibilities, benefits and grievance processes. Conservation interventions should be evaluated against social as well as ecological outcomes, particularly where access restrictions or infrastructure projects affect livelihoods.

Research priorities and recommended methods

1. Spatial mapping of habitat and land-use change

A priority is to build a spatially explicit baseline of forest cover, habitat types, settlements, roads, streams, fire history and land-use transitions. Multi-date satellite imagery can be used to estimate change, with classification accuracy reported and field verification conducted at representative locations. The analysis should identify not only total forest area but also patch size, edge density, distance between patches, bottlenecks and potential barriers. Results should be reproducible, with the imagery dates, resolution, classification method and validation data documented.

2. Field validation of candidate corridors

Potential corridors identified through remote sensing or least-cost modelling should be validated using camera traps, track and sign surveys, opportunistic verified records and, where feasible, genetic samples. Survey placement should cover candidate routes and comparison areas, with repeat sampling across seasons. Detection probability must be considered because a lack of records does not necessarily indicate absence. Sensitive species locations should be handled responsibly to reduce risks of disturbance or illegal activity.

3. Occupancy, movement and genetic connectivity

Occupancy models can estimate site use while accounting for imperfect detection when repeat-visit data are available. GPS telemetry may provide direct movement information for selected species where ethical, legal and logistical conditions allow. Non-invasive genetic sampling can help assess relatedness and gene flow across landscape units. These methods answer different questions: occupancy measures use of sites, telemetry measures individual movement, and genetics can reveal longer-term connectivity. Their results should be integrated rather than treated as interchangeable.

4. Monitoring infrastructure-related mortality

Road mortality and barrier effects should be assessed through systematic carcass searches, traffic counts, road characteristics and wildlife crossing observations. Search intervals, observer effort and carcass persistence must be documented to avoid biased estimates. Where mitigation structures are installed, monitoring before and after construction, ideally with comparison sites, can test whether animal passage or mortality changes.

5. Community-based and socio-economic research

Research should document the distribution of resource dependence, conflict experiences, attitudes toward conservation, access to compensation and the perceived benefits and costs of tourism or restoration. Sampling should be ethically designed and should not treat communities as homogeneous. Participatory mapping can identify areas of seasonal use and conflict, while interviews can explain why certain interventions are feasible or unacceptable. Social data should be stored securely and reported without exposing sensitive household or wildlife locations.

6. Data management and open science

A landscape observatory could combine georeferenced biodiversity records, camera-trap metadata, land-cover maps, fire records, road-mortality observations and community-reported events. Each record should include date, method, effort, observer or source, taxonomic confidence and a clear provenance trail. Data standards and quality-control rules would allow later researchers to distinguish validated observations from unverified reports. Public sharing should be balanced with protection of sensitive species locations and personal information.

Table 1: Main pressures, likely mechanisms and evidence needed

Pressure or driver	Potential ecological mechanism	Priority evidence or indicator
Forest-cover change	Habitat loss, edge effects, altered understory and patch isolation	Validated multi-date land-cover maps; patch metrics; field vegetation checks
Roads and linear infrastructure	Collision mortality, movement barriers, noise and access effects	Traffic data, systematic carcass surveys, camera traps, crossing-use monitoring
Resource use and grazing	Changes in vegetation structure, regeneration and disturbance	Seasonal resource-use mapping, vegetation plots, participatory interviews
Human–wildlife interactions	Livestock or crop loss, retaliation risk and altered movement	Verified incident database, response times, species and season records
Fire and drought	Changes in vegetation recovery, cover and water availability	Fire history, rainfall and water data, repeat vegetation and wildlife surveys
Tourism and settlement growth	Disturbance, waste, traffic and new access routes	Visitor counts, disturbance monitoring, waste audits and spatial expansion mapping

Table 2: Suggested research programme

Time horizon	Priority action	Expected deliverable
Short term	Compile verified biodiversity and incident records; establish spatial baseline	Curated database and documented evidence gaps
Short term	Map forest cover, roads, streams, settlements and candidate bottlenecks	GIS layers and preliminary connectivity assessment
Medium term	Deploy repeat camera-trap and sign-survey designs across candidate corridors	Site-use estimates with uncertainty
Medium term	Monitor road mortality and test selected mitigation measures	Risk maps and evaluated mitigation outcomes
Long term	Integrate genetic, movement, habitat and community data	Adaptive landscape conservation plan

Management recommendations

First, protect existing habitat links before attempting restoration. Intact forest patches and narrow bottlenecks may be disproportionately important for movement and are often harder to replace once converted. Proposed land-use changes should be evaluated against current habitat maps, verified wildlife records and connectivity models, with uncertainty explicitly stated.

Second, use restoration selectively. Restoration should target degraded patches or bottlenecks where evidence indicates that vegetation recovery would improve habitat function. Planting trees in naturally open habitats or changing stream margins without ecological assessment may damage other biodiversity values. Species composition, hydrology, soil and reference ecosystems should guide restoration choices.

Third, apply wildlife-sensitive infrastructure planning. New or upgraded roads and other linear structures should be screened for movement routes and mortality risk. Mitigation should be designed for the species and landscape context, followed by post-construction monitoring. Avoidance of critical habitat is generally preferable to attempting to compensate for its loss.

Fourth, strengthen community-based coexistence measures. Conflict response, compensation, livestock protection, resource governance and tourism planning should be transparent and locally appropriate. Benefits from conservation and tourism should be fairly distributed, and local knowledge should inform decisions about seasonal access and resource use.

Fifth, institutionalize long-term monitoring. A shared monitoring framework among the forest department, research institutions, local communities and independent researchers could track habitat condition, wildlife use, road mortality, conflict and restoration outcomes. Annual reporting should distinguish activities completed from ecological outcomes achieved.

Finally, use adaptive management. Management actions should be treated as interventions whose effects are measured. Where evidence is uncertain, pilot studies and

comparison sites can reduce the risk of applying costly measures without knowing whether they work.

Conclusion

The Melghat landscape is important for biodiversity conservation because its dry deciduous forests, valleys, grasslands, streams and buffer lands form part of a wider Central Indian ecological system. Long-term conservation depends on maintaining habitat quality within protected areas while retaining functional connections across surrounding human-used landscapes. Earlier national assessments and scientific studies support the importance of the wider Satpura–Melghat context and highlight the need to improve understanding of forest-cover change, infrastructure effects and species-specific habitat use.

The most defensible next step is a coordinated research programme that links spatial analysis with field validation, movement or occupancy evidence, road-risk monitoring and community-based data. Conservation decisions should distinguish established findings from plausible mechanisms and untested assumptions. By combining ecological monitoring with participatory governance and adaptive management, Melghat can be approached as a connected socio-ecological landscape rather than as an isolated protected area.

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