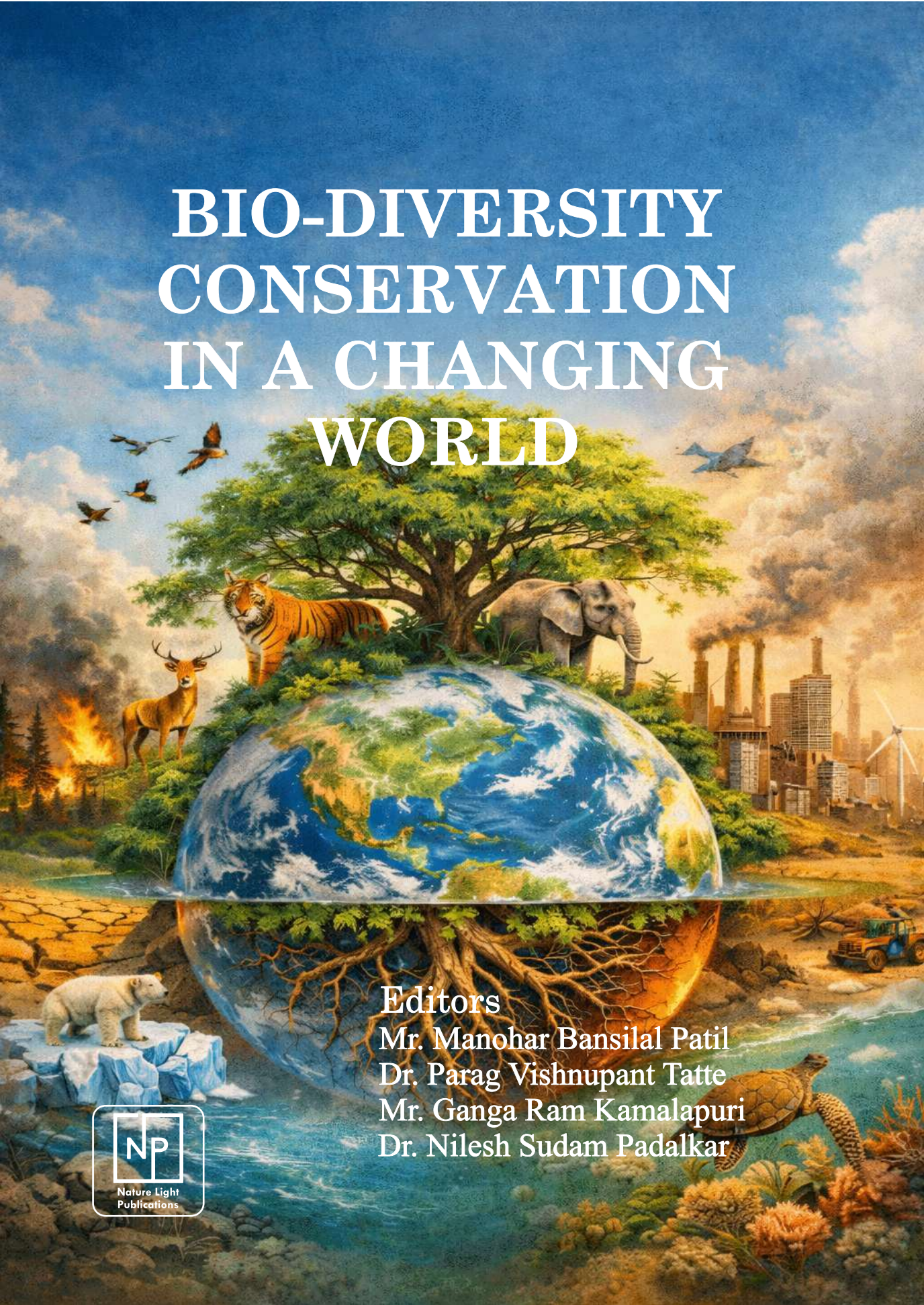


BIO-DIVERSITY CONSERVATION IN A CHANGING WORLD



Editors

Mr. Manohar Bansilal Patil

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Preface

Biodiversity, the intricate web of life that sustains ecosystems and human well-being, is facing unprecedented challenges in the 21st century. Rapid environmental changes driven by climate change, habitat loss, pollution, and unsustainable resource use have intensified pressures on natural systems across the globe. In this context, the edited volume “Bio-Diversity Conservation in a Changing World” seeks to provide a comprehensive and timely exploration of the evolving dimensions of biodiversity conservation, with a special focus on India.

This book brings together a diverse collection of scholarly contributions that highlight both the urgency of conservation efforts and the innovative pathways being developed to address these challenges. The chapters collectively emphasize that biodiversity conservation is no longer a standalone environmental concern but a critical foundation for sustainable development, ecological balance, and human survival.

The opening chapter on Innovative Strategies for Biodiversity Conservation in India sets the tone by integrating scientific approaches with ecosystem restoration and community stewardship, underscoring the importance of participatory and interdisciplinary methods. Subsequent discussions on The Future Challenges of Biodiversity Conservation in India and broader global perspectives further illuminate the complexities and uncertainties that lie ahead.

A significant highlight of this volume is its alignment with global sustainability frameworks, particularly through the chapter on Biodiversity Conservation as a Foundation for Achieving the Sustainable Development Goals (SDGs). This reinforces the idea that conservation is integral to addressing poverty, health, climate resilience, and economic development.

Technological advancements are also explored, notably in Technological Innovations in Avian Biodiversity Monitoring, which showcases how modern tools and techniques are transforming ecological research and conservation

practices. Regional case studies, such as the impact of wildlife ecotourism in Chandrapur District and forest biodiversity management in Bhandara District, Maharashtra, provide valuable insights into local dynamics and community interactions.

The book further expands its scope by addressing specific taxa and ecosystems, including butterflies under changing climatic conditions and corticioid fungi diversity in Himachal Pradesh. These contributions highlight the importance of lesser-studied organisms and ecosystems in maintaining ecological integrity.

Finally, policy-oriented discussions, such as the chapter on Clean Development Mechanism and Climate Change Policy in India, bridge the gap between science and governance, emphasizing the need for integrated and forward-looking policy frameworks.

This volume is intended for researchers, academicians, policymakers, environmental practitioners, and students who are engaged in biodiversity conservation and sustainable development. By combining theoretical insights, empirical studies, and practical approaches, the book aims to inspire informed action and foster collaborative efforts toward conserving biodiversity in an ever-changing world.

We extend our sincere gratitude to all contributors for their valuable research and insights, and to the readers who share a commitment to safeguarding our planet's biological heritage for future generations.

Editors

Bio-Diversity Conservation in a Changing World

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Bio-Diversity Conservation in a Changing World

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Innovative Strategies for Biodiversity Conservation in India: Integrating Science, Ecosystem Restoration and Community Stewardship

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Abstract

Biodiversity loss has emerged as one of the most serious environmental challenges of the present century, threatening ecosystem stability, ecological services, and sustainable human development. India, one of the world's megadiverse countries, harbors rich biological wealth across forests, grasslands, wetlands, mountains, and coastal ecosystems. However, this biodiversity is increasingly under pressure due to habitat fragmentation, invasive species, deforestation, pollution, overexploitation of natural resources, illegal wildlife trade, and climate change. In this context, the present chapter examines innovative strategies for biodiversity conservation in India with special emphasis on scientific assessment, ecosystem restoration, species reintroduction, technological monitoring, and community stewardship.

The chapter is based on field-oriented biodiversity observations, faunal surveys, habitat evaluation, and conservation-based analysis. Particular attention is given to the reintroduction of cheetahs into Kuno National Park, Madhya Pradesh, as a landmark example of rewilding and ecological restoration. The study highlights the role of legislative support, protected areas, wildlife corridors, captive breeding, germplasm conservation, invasive species management, satellite-based habitat assessment, GPS tracking, and public awareness in biodiversity conservation. It

further proposes an integrated conceptual framework in which scientific research, habitat restoration, species recovery, technological innovation, and policy-supported community participation function as interconnected pillars of long-term conservation.

The chapter concludes that biodiversity conservation in India requires a multidisciplinary and adaptive approach that combines ecological science with governance, local participation, and technological advancement. Such innovative and integrated strategies are essential not only for the protection of species and ecosystems, but also for maintaining ecological balance and ensuring sustainable development for future generations.

Keywords: Biodiversity conservation, ecosystem restoration, rewilding, cheetah reintroduction, wildlife corridors, habitat restoration, ecological monitoring, GPS tracking, satellite remote sensing, sustainable ecosystems.

Introduction

The world is dealing with the loss of biological diversity, which has become a major global environmental crisis. Biodiversity represents the variety of living organisms including plants, animals, and microorganisms that form complex ecological interactions within ecosystems. However, rapid industrialization, habitat destruction, deforestation, climate change, and overexploitation of natural resources have resulted in a significant decline in biodiversity worldwide.

India is recognized as one of the world's megadiverse countries, possessing diverse ecosystems ranging from the Himalayan mountains to tropical forests, wetlands, grasslands, deserts, and coastal regions. These ecosystems support a wide variety of flora and fauna that contribute to ecological stability and human well-being. Despite this rich biodiversity, many species and ecosystems in India are facing increasing threats due to anthropogenic pressures.

In recent decades, biodiversity conservation approaches have evolved from traditional species protection toward ecosystem-based management strategies. Innovative conservation initiatives such as habitat restoration, wildlife corridors, species reintroduction, and community-based conservation programs have gained increasing importance. The reintroduction of cheetahs into Kuno National Park in Madhya Pradesh represents a significant milestone in India's conservation history, symbolizing efforts to restore ecological balance and revive degraded grassland ecosystems.

Modern technological tools such as satellite remote sensing, geographic information systems (GIS), and GPS tracking have further enhanced the ability of researchers and conservationists to monitor biodiversity and manage ecosystems effectively. These approaches provide valuable insights into wildlife movement, habitat conditions, and environmental changes.

The present chapter explores innovative strategies for biodiversity conservation in India and highlights the importance of integrating scientific research, technological innovation, policy frameworks, and community participation to achieve sustainable ecosystem management.

Objectives

The study was conducted with the following objectives:

- To conserve biological diversity by protecting species and maintaining ecological balance.
- To assess faunal biodiversity through field surveys and ecological monitoring.
- To identify innovative strategies for biodiversity conservation in India.
- To evaluate ecosystem restoration initiatives such as species reintroduction programs.
- To identify major threats affecting biodiversity and propose effective conservation measures.
- To promote environmental awareness and community participation in biodiversity conservation.
- To strengthen biodiversity management through policy and scientific approaches.

Methodology

The study adopted a multidisciplinary approach combining field-based biodiversity surveys, ecological monitoring, and technological tools for conservation analysis.

1. Study Area and Site Survey

Field investigations were carried out in selected regions of central India. Among several surveyed locations, Kuno National Park in Madhya Pradesh was identified as a suitable site for biodiversity conservation due to its favorable habitat conditions and adequate prey base.

2. Faunal Biodiversity Survey

Systematic faunal surveys were conducted to document species diversity and distribution. Various ecological techniques such as transect surveys, field observations, and species identification methods were used to monitor wildlife populations.

3. Collection and Preservation of Small Fauna

Small fauna including insects were collected and preserved for identification and biodiversity analysis. Standard entomological techniques were used for collection and preservation.

4. Ecological Data Analysis

Collected data were analyzed using biodiversity indices and statistical methods to determine species richness and ecological relationships. Rarefaction diversity methods were used for biodiversity evaluation.

5. Species Reintroduction Study

The reintroduction of cheetahs into Kuno National Park was studied as an example of ecosystem restoration and wildlife conservation.

6. Technological Tools

Modern technologies such as satellite observation, GIS mapping, and GPS tracking were used to monitor wildlife movement patterns and detect anthropogenic pressures on ecosystems.

Conceptual Framework for Innovative Biodiversity Conservation Strategies

Modern biodiversity conservation requires an integrated framework that combines scientific research, ecosystem management, technological innovation, and community participation.

Five major pillars of biodiversity conservation are proposed:

- Scientific Research and Biodiversity Assessment
- Habitat Protection and Ecosystem Restoration
- Species Conservation and Reintroduction Programs
- Technological Innovations in Biodiversity Monitoring
- Community Participation and Policy Support

These interconnected components collectively contribute to sustainable biodiversity conservation.

Innovative Strategies for Biodiversity Conservation

Several innovative strategies have been implemented for biodiversity conservation in India.

Government Legislation: Legal frameworks such as the Wildlife Protection Act and Biodiversity Act provide protection for endangered species and ecosystems.

Important legislative measures include:

- Wildlife Protection Act (1972) for protection of wildlife species and creation of national parks and wildlife sanctuaries.
- Biological Diversity Act (2002) for conservation and sustainable use of biological resources.
- Forest Conservation Act (1980) to regulate deforestation and protect forest ecosystems.
- National Biodiversity Authority (NBA) which monitors biodiversity conservation programs.

These legislative mechanisms help regulate activities such as poaching, illegal wildlife trade, habitat destruction, and exploitation of natural resources.

Table 1: Major Biodiversity Conservation Programs in India

Program	Year	Objective
Project Tiger	1973	Conservation of Bengal tiger populations
Project Elephant	1992	Protection of Asian elephants and their habitats
Project Snow Leopard	2009	Conservation of high-altitude Himalayan ecosystems
Project Cheetah	2022	Reintroduction of cheetahs to restore grassland ecosystems

Establishment of Protected Areas: Protected areas form the backbone of biodiversity conservation strategies. India has developed an extensive network of protected areas including:

- National Parks
- Wildlife Sanctuaries
- Biosphere Reserves
- Conservation Reserves
- Community Reserves

These protected areas help preserve critical habitats and maintain ecological processes. For example:

- Kaziranga National Park protects the endangered one-horned rhinoceros.
- Gir National Park conserves the Asiatic lion.
- Sundarbans Biosphere Reserve protects mangrove ecosystems and the Royal Bengal tiger.

Protected areas also serve as important research and ecological monitoring sites.

Habitat Restoration and Ecosystem Rehabilitation: Habitat degradation is one of the major causes of biodiversity loss. Restoration of degraded habitats is therefore essential for sustaining biodiversity. Activities such as reforestation, wetland restoration, Soil and water conservation and grassland management help restore degraded ecosystems.

Restoration activities improve soil fertility, vegetation cover, and ecosystem productivity, thereby supporting wildlife populations.

Reintroduction and Rewilding of Species: The reintroduction of cheetahs into Kuno National Park represents a landmark conservation initiative aimed at restoring ecological balance. The project represents one of the world's first intercontinental large carnivore translocation efforts.

Benefits of species reintroduction include:

- Restoration of ecological balance

- Regulation of prey populations
- Revitalization of degraded ecosystems
- Enhancement of biodiversity conservation awareness

Reintroduction programs require careful evaluation of habitat suitability, prey availability, and ecological compatibility.



Captive Breeding and Seed Banks: Captive breeding programs and seed banks help preserve endangered species and genetic diversity. These programs involve breeding threatened species in controlled environments such as:

- Zoological parks
- Botanical gardens
- Conservation breeding centers

Examples include

- Crocodile breeding programs in India
- Red panda breeding initiatives in Himalayan regions

Similarly, seed banks and gene banks are established to preserve plant genetic diversity for future restoration programs.

Management of Invasive Species: Management of invasive species prevents ecological imbalance and protects native biodiversity.

Maintenance of Ecological Food Chains: Maintaining balanced food chains is essential for ecosystem stability. Every species plays a specific role within the trophic structure.

Conservation programs therefore focus on:

- Protecting predator populations
- Maintaining herbivore populations
- Conserving primary producers and decomposers

Disruption of any level in the food chain can lead to ecological imbalance and biodiversity decline.

Wildlife Corridors and Landscape Connectivity: Habitat fragmentation restricts wildlife movement and genetic exchange between populations. Establishing wildlife corridors helps connect fragmented habitats.

Examples of wildlife corridor initiatives include:

- Elephant corridors in the Western Ghats and Northeast India
- Animal overpasses and underpasses on highways such as the Delhi–Mumbai Expressway

These corridors allow animals to migrate safely, maintain genetic diversity, and adapt to environmental changes.



Animal Bridge on Delhi-Mumbai Express way

Application of Modern Technologies in Conservation: Technological innovations have significantly improved biodiversity monitoring and conservation planning.

Important tools include:

- Satellite-based remote sensing for monitoring habitat changes
- GIS mapping for biodiversity distribution analysis
- GPS tracking for studying wildlife movement patterns
- Camera traps for monitoring elusive species

Satellite Earth observation data can help identify anthropogenic pressures such as deforestation, mining, and urbanization in sensitive ecosystems.

Protection of Genetic Resources: Genetic diversity is fundamental for species survival and adaptation. Conservation of genetic resources involves:

- Germplasm preservation
- Genetic research and lineage identification
- Biotechnology-based conservation methods

Tissue culture techniques are widely used to multiply rare plant species and restore degraded habitats.

Regulation of Wildlife Trade and Overexploitation: Illegal wildlife trade is one of the major threats to biodiversity. International and national organizations regulate wildlife trade to protect endangered species.

Important agencies include:

- CITES (Convention on International Trade in Endangered Species)
- TRAFFIC wildlife trade monitoring network

These organizations help control poaching and illegal trade of wildlife products such as ivory, skins, horns, and medicinal plants.

Community Participation and Public Awareness: Local communities play a vital role in biodiversity conservation. Community-based conservation approaches involve:

- Participation of local people in forest management
- Promotion of eco-tourism
- Environmental education programs

Awareness programs help people understand the importance of biodiversity and encourage sustainable utilization of natural resources.

Climate Change Mitigation and Sustainable Practices: Climate change is emerging as a major threat to biodiversity. Conservation strategies must therefore integrate climate adaptation measures such as:

- Restoration of carbon-sequestering ecosystems (forests and wetlands)
- Promotion of sustainable agriculture practices
- Reduction of pollution and greenhouse gas emissions

Such strategies enhance ecosystem resilience and protect biodiversity under changing environmental conditions.

Table 2: Innovative Conservation Technologies

Technology	Application
Remote Sensing	Monitoring deforestation and habitat changes
GIS Mapping	Mapping biodiversity distribution
GPS Tracking	Monitoring wildlife movement patterns
Camera Traps	Studying elusive and nocturnal species
Molecular Genetics	Studying genetic diversity of species

Discussion

Biodiversity conservation requires integrated approaches that combine ecological science, policy support, and community involvement. Modern conservation programs emphasize ecosystem-based management rather than species-specific protection.

The reintroduction of cheetahs into Kuno National Park demonstrates how scientific planning and habitat restoration can contribute to ecosystem recovery. Technological tools such as remote sensing and GPS monitoring provide accurate information for conservation planning.

However, challenges such as habitat fragmentation, illegal wildlife trade, invasive species, and climate change continue to threaten biodiversity. Addressing these issues requires stronger conservation policies and sustainable resource management.

Conclusion

Biodiversity is essential for maintaining ecological stability and supporting human life. The study highlights that innovative biodiversity conservation strategies must integrate habitat restoration, species protection, technological monitoring, and community participation.

The successful implementation of such strategies will help protect biodiversity, maintain ecological balance, and ensure sustainable environmental management for future generations.

Recommendations / Future Perspectives

- Strengthening biodiversity monitoring using modern technologies.
- Expanding protected areas and wildlife corridors.
- Promoting community-based conservation initiatives.
- Controlling invasive species and illegal wildlife trade.
- Encouraging sustainable agriculture and land-use practices.
- Increasing environmental awareness and education programs.

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The Future Challenges of Biodiversity Conservation in India

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Abstract

India is a mega diverse nation that supports approximately 7% to 8% of the world's recorded species within merely 2.4% of the global land area. This research paper provides a comprehensive analysis of the contemporary and future challenges facing biodiversity conservation in India. The study highlights the current status of the country's four global biodiversity hotspots and its extensive Protected Area (PA) network, which has expanded to 1,014 designated sites. Despite these achievements, the analysis identifies critical stressors, including habitat fragmentation, land degradation affecting nearly 30% of the geographical area, the proliferation of invasive alien species, and the pervasive impacts of climate change. The research paper evaluates the shift from a flagship species centric approach toward a holistic ecosystem-based strategy, as outlined in the updated National Biodiversity Strategy and Action Plan (NBSAP) 2024-2030. Special attention is given to the role of emerging technologies, such as artificial intelligence, environmental DNA (e-DNA), and cyber taxonomy, in overcoming logistical barriers to biodiversity monitoring. The findings suggest that long term resilience requires a paradigm shift that integrates "Institutional Reserves" on non-protected landscapes and aligns national conservation targets with the Kunming Montreal Global Biodiversity Framework. The research paper concludes with evidence-based recommendations for policy interventions aimed at balancing socio-economic development with the preservation of India's unique evolutionary heritage.

Keywords: Biodiversity Conservation, Protected Area Network, Climate Change Adaptation, Ecosystem Restoration.

Introduction

The preservation of biological diversity in India is not merely an environmental concern but a fundamental necessity for ecological stability and socio-economic survival. As one of the world's 17 mega diverse countries, India's biological richness is a product of its diverse topography, ranging from the trans-Himalayan alpine zones to the tropical rainforests of the Western Ghats and the extensive mangrove networks of the Sundarbans. This wealth is manifested in the presence of four global biodiversity hotspots: the Himalayas, the Western Ghats, the Indo-Burma region, and Sundaland. These regions are centers of high endemism, hosting species found nowhere else on the planet, yet they are simultaneously areas of intense anthropogenic pressure.

Historically, India has demonstrated a strong commitment to conservation through legislative frameworks like the Wildlife (Protection) Act of 1972 and the Biological Diversity Act of 2002. These laws have facilitated the establishment of a vast Protected Area (PA) network, which currently encompasses National Parks, Wildlife Sanctuaries, Conservation Reserves, and Community Reserves. The success of flagship initiatives such as Project Tiger and Project Elephant has led to significant recoveries in the populations of iconic species, with the tiger population reaching an estimated 3,682 individuals by 2022. However, this "numbers game" has occasionally resulted in a disproportionate focus on charismatic megafauna, often at the expense of broader ecosystem health and the requirements of lesser-known taxa.

As the global community moves toward the targets set by the Kunming-Montreal Global Biodiversity Framework (KMGBF), India faces a pivotal decade. The Seventh National Biodiversity Paper (NR7) indicates that while policy alignment is high, substantial structural challenges remain. Land degradation affects approximately 97 million hectares of the national territory, and the "30x30" goal conserving 30% of terrestrial and marine areas by 2030—presents a daunting task given that formal PAs currently cover only 5.32% of the land. Furthermore, the introduction of invasive alien flora and the overarching threat of climate change are altering habitat suitability, forcing species into contracted ranges or leading to local extinctions.

The future of conservation in India necessitates an evolution beyond "fortress conservation" toward a landscape-level approach. This involves integrating non-protected landscapes, such as academic campuses and defense lands, into the conservation matrix through the establishment of "Institutional Reserves". Simultaneously, the integration of advanced biotechnological and digital tools is required to provide the high-resolution data necessary for adaptive management in an era of rapid environmental flux. This paper synthesizes these multi-dimensional challenges and opportunities to provide a strategic roadmap for the future of Indian biodiversity.

Reviews of Literatures

The discourse on biodiversity conservation in India has transitioned from descriptive species accounts to complex, model-based analyses of socio-ecological systems. The following reviews highlight the key theoretical and empirical contributions to the field.

- **Sarkar, D., Jagannivsan, H., Debnath, A., & Talukdar, G. (2024):** This study conducted a systematic literature review to assess the impacts of future climate change on India's biodiversity using species distribution model (SDM) studies. The authors identified a significant surge in research after 2015, primarily focused on the Himalayan and Western Ghats regions. A key finding was the "taxonomic bias" in current research, where plants are the most studied group (n=77), while invertebrates and other lesser-studied taxa receive minimal attention despite their critical ecological roles. The review emphasizes the urgent need for pan-India modeling to identify potential climate refugia for endemic species.
- **Boyapati, T., & Muthukumarappan, K. K. (2025):** This research examines the role of non-timber forest products (NTFPs) in the bioeconomy, specifically focusing on livelihood dependence among indigenous and tribal populations in India. The meta-analysis indicates that NTFPs contribute up to 40% of the annual income for land-constrained households. However, the authors caution that commercialization without robust post-harvest innovations and regulatory safeguards could lead to over-extraction and the degradation of forest ecosystems. They advocate for a rights-based governance model that balances economic extraction with biodiversity goals.
- **Solanki, G. S. (2025):** Solanki proposes a paradigm shift in Indian conservation strategy by advocating for species conservation beyond the legal boundaries of the Protected Area network. The study introduces the concept of "Institutional Reserves," arguing that modified landscapes under the control of academic institutions, defense sectors, and non-governmental organizations can serve as vital refuges for regional biodiversity. Case studies presented in the paper demonstrate that well-managed campuses can support a high diversity of avian and small mammalian fauna, providing a framework for expanding conservation coverage in human-dominated landscapes.
- **Dar, S. A., Dar, S. A., & Nabi, M. (2022):** This comprehensive review analyzes the current status and future strategies for biodiversity conservation in India. The authors highlight that despite India's strong scientific and technological foundation; the country faces systemic challenges such as habitat fragmentation and plastic pollution. They note that the Environmental Performance Index (EPI) rankings for India have room for significant improvement. The study concludes that a "people-centered" approach, involving active stakeholder participation and the enhancement of data

collection methodologies, is essential for sustaining ecosystem services in the long term.

- **Wani, Z. A., Dar, J. A., Lone, A. A. N., Pant, S., & Siddiqui, S. S. (2025):** Focused on the Western Himalayan landscape, this research utilizes the ‘Surya-Kunj’ model site to evaluate the impact of forest restoration activities on biodiversity conservation. The study provides longitudinal data showing that native Himalayan species exhibit a significantly higher survival rate (62%) compared to non-native species (38%). The authors argue that ecological restoration is most successful when it integrates native species with community consultation, offering a replicable framework for restoring degraded mountain ecosystems.

Objectives

The primary objectives of this research paper are:

- To evaluate the current statistical profile of India’s biodiversity, including species richness, endemism, and the status of the Protected Area network.
- To analyze the primary drivers of biodiversity loss in India, with a focus on habitat fragmentation, land degradation, invasive alien species, and climate change.
- To assess the progress toward the 23 national biodiversity targets aligned with the Kunming Montreal Global Biodiversity Framework.
- To investigate the potential of emerging technologies and alternative conservation frameworks, such as cyber-taxonomy and Institutional Reserves, in enhancing conservation efficacy.
- To provide evidence-based recommendations for policy interventions and future research directions to ensure long-term ecological resilience.

Data Base and Methodology

The findings of this paper are synthesized from a multi-institutional database encompassing official governmental papers, international environmental assessments, and peer-reviewed scientific literature. The primary data sources include:

- **The Seventh National Biodiversity Paper (NR7):** Submitted by the Ministry of Environment, Forest and Climate Change (MoEFCC), this paper evaluates India’s performance against 142 national indicators used to assess progress toward 2030 targets.
- **The National Wildlife Database:** Maintained by the Wildlife Institute of India (WII), providing updated statistics on the Protected Area network, including Tiger and Elephant Reserves.
- **Indian State of Forest Papers (ISFR):** Biennial updates from 2021 and 2023 were utilized to track changes in forest cover, bamboo area, and carbon stocks.

- **The Desertification and Land Degradation Atlas of India:** This source provided quantitative data on the extent of land degradation across various biogeographic zones.
- **Systematic Literature Reviews (2015-2025):** Meta-analyses of species distribution modeling (SDM), environmental DNA (eDNA) applications, and forest restoration case studies were reviewed to identify emerging trends and data gaps.

The methodology employed a thematic synthesis of qualitative insights and quantitative data. A gap analysis was performed to compare current conservation outcomes against the “30x30” global goal. Case study evaluations were conducted for specific models, such as the ‘Surya-Kunj’ arboretum and the Corbett Tiger Reserve, to understand the local implications of habitat management and restoration. The analysis also integrated financial data from the MoEFCC regarding budgetary allocations for wildlife habitat development and species recovery programs.

Result and Discussion

The results of the analysis indicate that India has made significant strides in policy alignment and the stabilization of flagship species, yet the country remains vulnerable to systemic ecological stressors. The discussion is structured to address the biogeographic framework, current biodiversity statistics, the effectiveness of the PA network, and the emerging threats that define the future of conservation.

1. Biogeographic Framework and Habitat Diversity

India is categorized into ten distinct biogeographic zones, each hosting a unique assemblage of flora and fauna. The vastness of the Deccan Peninsula and the high endemism of the Himalayan and Western Ghats regions form the backbone of the country’s biological wealth.

Table No. 1.1

S. No.	Biogeographic Zone	Representative Regions/Provinces	Area (km ²)
1	Trans-Himalaya	Ladakh mountains, Tibetan plateau	1,74,225
2	Himalaya	Northwest, West, Central and East Himalayas	2,10,386
3	Desert	Thar, Kutch	2,13,672
4	Semi-arid	Punjab plains, Gujarat Rajputana	5,45,686
5	Western Ghats	Malabar plains, Western Ghats	1,31,490

6	Deccan Peninsula	Central highlands, Chhota-Nagpur, Deccan South	13,77,363
7	Gangetic Plains	Upper and Lower Gangetic plains	3,55,025
8	Coast	West and East coast, Lakshadweep	82,182
9	North-East	Brahmaputra valley, Northeast hills	1,70,937
10	Islands	Andaman and Nicobar	12,972

Source: Ministry of Statistics and Programme Implementation (MoSPI) and BSI.

The table no. 1.1 highlights that while the Deccan Peninsula covers the largest geographical area, the smaller zones such as the Islands and the North-East host disproportionately high levels of endemism per unit area. The concentration of conservation effort in larger zones must be balanced with intensive protection in these smaller, species-rich “islands” of diversity.

2. Current Status of Floral and Faunal Diversity

India’s contribution to global biodiversity is substantial, accounting for approximately 7.43% of the world’s faunal species and 11% of the world’s flora. Recent discoveries continue to update these inventories.

Table No. 1.2

Taxonomic Group	Number of Species	Global Share (%)	Endemism in India (%)
Mammals	350	7.6%	Moderate
Birds	1,224	12.6%	Low to Moderate
Reptiles	456+	-	47%
Amphibians	254+	-	61.2%
Fishes	2,546	11.7%	High
Flowering Plants	18,666	-	27-33%
Total Fauna	1,02,161	7-8%	28%

Source: Botanical Survey of India (BSI) and Zoological Survey of India (ZSI), 2019-2024.

The table no. 1.2 underscores the exceptional endemism in Amphibia (61.2%) and Reptilia (47%), which are primarily concentrated in the Western Ghats and Himalayan hotspots. This high endemism implies that the extinction of a species in these regions represents a global loss of that lineage. The steady discovery of new species such as the 41 plant species added by BSI in 2007 suggests that the actual

biodiversity may be even higher, particularly in under-explored microbial and invertebrate groups.

3. The Protected Area Network: Expansion and Gaps

The primary strategy for conserving this diversity is the Protected Area (PA) network. As of 2024, the network has surpassed 1,000 units, covering a significant portion of the forest estate.

Table No. 1.3

Category	Number (2023)	Area (km ²)	Geographical Area
National Parks	106	44,402.95	1.35%
Wildlife Sanctuaries	573	127,277.88	3.87%
Conservation Reserves	115	5,585.30	0.17%
Community Reserves	220	1,903.29	0.06%
Total	1,014	175,169.42	5.32%

Source: WII National Wildlife Database and PIB, 2024.

In the table no. 1.3 show that evolution of the protected area network in 2023-2024. The number of PAs is impressive, the total coverage of 5.32% is significantly lower than the global target of 30%. Furthermore, many of these areas are “isolated islands” within a matrix of human-dominated landscapes. The administrative boundaries of PAs often do not align with ecological boundaries, leading to challenges in managing wide ranging species like elephants and tigers. The disproportionately small area allocated to Community and Conservation Reserves (<0.3%) suggests that community led conservation remains under-utilized as a formal legal tool.

4. Flagship Species Success and the Management Dilemma

India’s conservation narrative is often defined by the success of its flagship species programs. The tiger population has seen a steady increase, reaching a minimum of 3,167 individuals (average estimated at 3,682) by 2022. Similarly, the Asiatic lion population in Gir grew from 411 in 2010 to 674 in 2020.

However, this success brings new challenges, termed the “problem of plenty”. In the Corbett Tiger Reserve, which hosts the highest tiger density in India, the focus on increasing the prey base (spotted deer) has led to habitat manipulation that stops natural ecological succession. This has negatively impacted the recovery of the endangered hog deer, which requires unmanaged, tall terai grasslands. The concentration of tigers in only 21% of available forest area suitable for them highlights a critical need for ecological corridors to facilitate dispersal and reduce human-wildlife conflict.

5. Land Degradation: A Pervasive Threat

Land degradation is the single most significant driver of biodiversity loss outside of direct habitat conversion. The Desertification and Land Degradation Atlas papers that 29.77% of India’s land (97 million hectares) are currently experiencing degradation.

Table No. 1.4

Driver	Affected Area/Metric	Impact on Biodiversity
Land Degradation	29.77% of geographical area	Loss of soil biota, reduced primary productivity
Invasive Alien Flora	Widespread in forest types	Displacement of native species, altered fire regimes
Plastic Pollution	High in urban/marine interfaces	Entanglement, ingestion, microplastic contamination
Climate Change	Projected 45% habitat loss	Range contraction, elevational shifts, local extinction

Source: NR7 Summary and Dar et al. (2022).

The table no. 1.4 ongoing land degradation undermines the success of restoration projects. Under the Bonn Challenge, India has pledged to restore 26 million hectares by 2030, with 24.1 million hectares already under restoration or completed. However, if the rate of new degradation exceeds the rate of restoration, the net gain in ecosystem vitality will remain stagnant.

6. Climate Change: Shifting Distributions and Niche Vulnerability

Climate change adds an overarching layer of complexity to conservation. Systematic reviews of species distribution models (SDMs) indicate that by 2050, suitable habitats for many endemic primates and plants will decline significantly.

In the Himalayas, experimental warming of 1.70C has been shown to alter soil respiration rates in alpine meadows, potentially disrupting the carbon sequestration capacity of these high-altitude ecosystems. For “niche” species like the dancing frog of the Western Ghats, even slight changes in the micro climate or stream composition can lead to breeding failure. The “trailing edge” of species’ ranges those at lower elevations or latitudes—are particularly vulnerable to local extinctions as they reach their physiological limits.

7. Technological Frontiers in Monitoring

To address the challenges of monitoring biodiversity in inaccessible terrains, India is deploying sophisticated technologies. The integration of ‘Cyber-taxonomy’ and ‘Artificial Intelligence’ allows for the rapid processing of large datasets, which is essential given the logistical constraints of manual surveys.

The interventions include:

- **Environmental DNA (e-DNA):** This tool has been used to study and recover threatened species like Irrawaddy dolphins and giant catfish by sampling environmental media without physical sightings.
- **Passive Acoustic Monitoring (PAM):** This technique allows for the detection of species in dense forest canopies where visual detection is nearly impossible.
- **Next-Generation DNA Sequencing:** The Wildlife Institute of India recently established a NGS facility in Dehradun to enhance research in wildlife genetics and the identification of cryptic species.
- **Satellite Tagging:** The successful satellite tagging of a Ganges River Dolphin in Assam in late 2024 represents a milestone in understanding the movement and habitat needs of riverine megafauna.

8. Case Study: Forest Restoration in the Western Himalaya

The ‘Surya-Kunj’ restoration model demonstrates the efficacy of integrating ecological principles with community participation.

Table No. 1.5

Category	Statistic	Implications
Native Species Success	62%	Higher resilience of indigenous flora
Non-Native Success	38%	Poor adaptation to Himalayan variables
Medicinal Plants	100 species	Restoration of ecosystem services (health)
Bird Diversity	>160 species	Restoration of higher trophic levels
Natural Regeneration	88 species	Transition to a self-sustaining ecosystem

Source: Wani et al. (2025).

The table no. 1.5 shows that the success of this model suggests that restoration should not be a “numbers game” of planting trees but a deliberate process of recreating complex forest structures. The high bird and butterfly diversity indicates that floral restoration successfully catalyzed faunal recovery.

9. The Paradigm Shift: Toward “Institutional Reserves”

The limitations of the formal PA network have led to the proposal of a paradigm shift. Solanki (2025) argues that biodiversity is not restricted to forests but exists in significant amounts on landscapes under the control of academic and defense institutions.

Case studies from Navsari Agricultural University and IIT Guwahati show that these campuses can host hundreds of avian species, including those classified as threatened. By recognizing these areas as “Institutional Reserves,” India can

significantly expand its conservation footprint without the socio-economic conflicts often associated with declaring new National Parks. This approach aligns with the “Other Effective Area-Based Conservation Measures” (OECM) framework currently being explored by the MoEFCC to meet the 30x30 goal.

10. Policy Alignment and the Seventh National Biodiversity Paper (NR7)

India’s updated NBSAP 2024-2030 outlines 23 national targets (NBTs) that mirror the global goals of the KMGBF. The NR7 paper, submitted in late 2024, provides a “reality check” on progress.

Table No. 1.6

Target	Description	Status	Key Progress/Gap
NBT 1	Spatial Planning	On Track	PARIVESH 2.0 digital platform launched
NBT 2	Ecosystem Restoration	On Track	24.1 million hectares under restoration
NBT 3	PA Coverage (30%)	Behind	Current coverage only 5.32%
NBT 6	Invasive Alien Species	Delayed	Lack of standardized monitoring protocols
NBT 7	Pollution Reduction	Delayed	Need for 50% reduction in pesticides

Source: NR7 Paper and Updated NBSAP.

In the table no. 1.6 shows that the India is “on track” for policy alignment and spatial planning, the actual implementation of pollution reduction and invasive species control is lagging. The real test of India’s commitment will lie in whether these “delayed” targets can be accelerated through increased budgetary allocations, which saw a 18% increase for Project Tiger and Elephant in the 2025-26 estimates.

Conclusions

The future challenges of biodiversity conservation in India are multi-dimensional, spanning ecological, technological, and socio-political domains. The current analysis demonstrates that while India has achieved remarkable success in stabilizing flagship species populations, the broader ecosystem health remains at risk. The “fortress conservation” model, while effective for certain taxa, is insufficient to address the pervasive threats of land degradation, climate change, and invasive species that operate across legal boundaries.

The following synthesis identifies the strategic path forward:

- **Landscape-Level Integration:** A transition from species-centric protection to ecosystem-centric management is required. This involves identifying and

protecting ecological corridors that facilitate the movement of wildlife across fragmented landscapes.

- **Formalizing OECMs:** The inclusion of non-protected landscapes, specifically through the “Institutional Reserve” framework, is essential for meeting the 30x30 global target. These modified habitats serve as critical refugia and connectivity hubs.
- **Technological Mainstreaming:** The scaling of e-DNA, AI-driven monitoring, and satellite tagging must move from research projects to standard management practices. High-resolution data is the only way to manage the “logistics problem” of India’s diverse and often inaccessible terrains.
- **Socio-Economic Resilience:** Conservation must be decoupled from the eviction of forest-dependent communities. Instead, the bio-economy must be strengthened by integrating NTFP rights and community-led restoration projects into the core of the NBSAP.
- **Addressing the “Silent Threats”:** Accelerated efforts are needed to control invasive alien flora and reduce plastic and chemical pollution, as these factors are “delayed” targets in the current national strategy despite their massive impact on ecosystem vitality.

India stands at a crossroads where its traditional scientific strength must meet a new, flexible governance model. If the nation can successfully integrate institutional landscapes and advanced monitoring into its conservation matrix, it will not only preserve its own natural heritage but also provide a replicable global model for mega diverse nations in the 21st century.

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Biodiversity Conservation as a Foundation for Achieving the Sustainable Development Goals

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Abstract

Biodiversity represents the variety of life on Earth, including genetic diversity, species diversity, and ecosystem diversity. It underpins ecosystem functioning and provides essential services that sustain human well-being. However, biodiversity loss has accelerated due to anthropogenic pressures such as habitat destruction, climate change, pollution, and unsustainable resource use. The global framework of the Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, recognizes the importance of biodiversity for sustainable development. This chapter examines the relationship between biodiversity and the SDGs, highlighting how biodiversity conservation contributes directly and indirectly to several global goals, including poverty reduction, food security, health, climate action, and ecosystem protection. It also discusses major threats to biodiversity, the role of governance and policy, and strategies for integrating biodiversity conservation into sustainable development planning. The chapter emphasizes that achieving the SDGs requires a holistic approach that values ecosystems and promotes sustainable management of natural resources.

Keywords: biodiversity, sustainable development goals, ecosystem services, conservation, environmental sustainability.

Introduction

Biodiversity is a fundamental component of the Earth's life-support system. It encompasses the diversity of species, genes, and ecosystems that sustain ecological processes and support human survival. Healthy ecosystems regulate climate, purify

water, maintain soil fertility, pollinate crops, and provide food, medicines, and materials essential for economic development (MEA, 2005). Despite its critical importance, biodiversity is declining at an unprecedented rate. Scientific assessments indicate that human activities such as deforestation, urban expansion, overexploitation of natural resources, and pollution have significantly disrupted natural ecosystems (IPBES, 2019). These pressures threaten not only wildlife but also the ecological services upon which societies depend.

In response to global environmental challenges, the United Nations introduced the Sustainable Development Goals (SDGs) in 2015 as part of the 2030 Agenda for Sustainable Development. The SDGs consist of 17 interconnected goals aimed at balancing economic development, environmental protection, and social well-being. Biodiversity is embedded across multiple goals, particularly those related to life on land, life below water, climate action, and sustainable consumption (UN, 2015). This chapter explores how biodiversity conservation contributes to achieving sustainable development. It analyzes the links between biodiversity and various SDGs and discusses policy and management strategies needed to integrate biodiversity into sustainable development frameworks.

Understanding Biodiversity

Biodiversity refers to the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems. It includes three main levels:

- **Genetic Diversity**

Genetic diversity refers to variation within species. It allows populations to adapt to environmental changes, resist diseases, and maintain long-term survival. Agricultural crops and livestock benefit greatly from genetic diversity, which enables breeders to develop improved varieties.

- **Species Diversity**

Species diversity refers to the number and variety of species in a particular area. High species diversity often reflects healthy ecosystems that can perform ecological functions efficiently.

- **Ecosystem Diversity**

Ecosystem diversity includes the range of ecosystems such as forests, wetlands, deserts, coral reefs, and grasslands. Each ecosystem provides unique services that support life on Earth. Together, these levels form the basis of ecosystem resilience and sustainability.

Concept of Sustainable Development

Sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). It integrates three major pillars:

- Environmental sustainability
- Social equity
- Economic growth



The concept emphasizes responsible resource management to ensure long-term ecological stability and human prosperity. Biodiversity plays a key role in maintaining this balance because ecosystems provide essential goods and services that support economic and social systems.

Overview of the Sustainable Development Goals

The Sustainable Development Goals are a global framework consisting of 17 goals and 169 targets aimed at addressing major global challenges by 2030. They cover areas such as poverty, hunger, education, health, climate change, and environmental protection. Several SDGs are directly connected to biodiversity conservation, including:

- SDG 2: Zero Hunger
- SDG 3: Good Health and Well-being
- SDG 6: Clean Water and Sanitation
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 14: Life Below Water
- SDG 15: Life on Land

Although only two goals explicitly focus on biodiversity (SDG 14 and SDG 15), many others depend on healthy ecosystems.

Biodiversity and Ecosystem Services

Biodiversity provides ecosystem services that are essential for human survival. These services are generally classified into four categories.

• Provisioning Services

Provisioning services include tangible products obtained from ecosystems such as food, freshwater, timber, fuelwood, fiber, and medicinal resources.

- **Regulating Services**

Regulating services include processes that regulate environmental conditions, such as climate regulation, flood control, disease regulation, and water purification.

- **Cultural Services**

Cultural services include recreational, aesthetic, spiritual, and educational benefits provided by nature.

- **Supporting Services**

Supporting services are fundamental ecological processes such as nutrient cycling, soil formation, and primary production that enable other ecosystem services to function. The loss of biodiversity reduces the capacity of ecosystems to provide these services, thereby affecting human livelihoods and development.

Role of Biodiversity in Achieving the Sustainable Development Goals

- **Biodiversity and SDG 1: No Poverty**

Many communities, particularly in developing countries, depend on natural resources for their livelihoods. Forest products, fisheries, and agricultural biodiversity provide income opportunities and support rural economies. Sustainable management of biodiversity helps reduce poverty by ensuring long-term resource availability.

- **Biodiversity and SDG 2: Zero Hunger**

Agricultural biodiversity plays a vital role in ensuring food security. Diverse crop varieties and livestock breeds enhance resilience to pests, diseases, and climate variability. Pollinators such as bees and butterflies also contribute significantly to crop production.

- **Biodiversity and SDG 3: Good Health and Well-being**

Biodiversity contributes to human health through medicinal resources and ecosystem regulation. Many pharmaceutical drugs are derived from plants, animals, and microorganisms. Healthy ecosystems also reduce the spread of diseases by maintaining ecological balance.

- **Biodiversity and SDG 6: Clean Water and Sanitation**

Wetlands, forests, and rivers play an essential role in maintaining water quality and regulating water flow. These ecosystems filter pollutants, reduce sedimentation, and replenish groundwater supplies.

- **Biodiversity and SDG 13: Climate Action**

Ecosystems such as forests, peat lands, and mangroves act as carbon sinks that absorb greenhouse gases from the atmosphere. Protecting these ecosystems contributes significantly to climate change mitigation and adaptation.

- **Biodiversity and SDG 14: Life Below Water**

Marine biodiversity supports fisheries, tourism, and coastal protection. Coral reefs and mangroves provide habitats for numerous marine species while protecting shorelines from erosion and storms.

- **Biodiversity and SDG 15: Life on Land**

SDG 15 specifically focuses on protecting terrestrial ecosystems, combating desertification, and halting biodiversity loss. Conservation of forests, grasslands, and wildlife habitats is essential for maintaining ecological balance.

Major Threats to Biodiversity

Despite its importance, biodiversity faces numerous threats resulting from human activities.

- **Habitat Loss**

Deforestation, urbanization, and agricultural expansion are major causes of habitat destruction. Loss of natural habitats leads to population decline and species extinction.

- **Climate Change**

Climate change alters temperature and precipitation patterns, affecting species distribution and ecosystem functioning.

- **Pollution**

Air, water, and soil pollution negatively impact ecosystems and biodiversity. Industrial waste, agricultural chemicals and plastic pollution are major environmental concerns.

- **Overexploitation**

Unsustainable harvesting of natural resources, including overfishing and illegal wildlife trade, threatens many species.

- **Invasive Species**

Non-native species can disrupt local ecosystems by competing with native species for resources. Addressing these threats requires coordinated global and local conservation efforts.

Strategies for Biodiversity Conservation

- **Protected Areas**

Establishing protected areas such as national parks, wildlife sanctuaries, and biosphere reserves is a key strategy for conserving biodiversity.

- **Sustainable Resource Management**

Promoting sustainable agriculture, forestry, and fisheries helps maintain ecosystem health while supporting economic development.

- **Community Participation**

Local communities play a crucial role in biodiversity conservation. Community-based resource management programs can enhance conservation outcomes.

- **Policy and Governance**

Effective environmental policies and regulations are necessary to protect biodiversity and ensure sustainable resource use.

- **Education and Awareness**

Environmental education increases public awareness about biodiversity conservation and encourages responsible behavior toward natural resources.

Integrating Biodiversity into Sustainable Development Policies

Integrating biodiversity considerations into national development plans is essential for achieving the SDGs. Governments can adopt several approaches:

- Incorporating biodiversity into land-use planning
- Promoting green infrastructure
- Supporting sustainable agriculture and forestry
- Encouraging biodiversity-friendly business practices
- Strengthening environmental monitoring systems
- International agreements such as the Convention on Biological Diversity (CBD) also provide a framework for global cooperation in biodiversity conservation.

Future Perspectives

Achieving sustainable development requires a transformative approach that prioritizes environmental sustainability. Advances in technology, ecological research, and policy innovation can support biodiversity conservation. Nature-based solutions, ecosystem restoration, and sustainable production systems are increasingly recognized as effective strategies for addressing global environmental challenges. Collaboration among governments, scientists, businesses, and communities will be essential to implement these strategies successfully.

Conclusion

Biodiversity forms the foundation of sustainable development by supporting ecosystem services that sustain human life and economic activities. The Sustainable Development Goals highlight the importance of protecting natural ecosystems and promoting responsible resource management. However, ongoing biodiversity loss poses significant challenges to achieving these goals. Addressing biodiversity decline requires integrated approaches that combine conservation, sustainable development, and social equity. Strengthening environmental governance, promoting sustainable resource use, and raising public awareness are essential steps toward safeguarding biodiversity for future generations. Ultimately, protecting biodiversity is not only an environmental priority but also a critical requirement for global sustainability and human well-being.

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Future Challenges in Biodiversity Conservation

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Abstract

Biodiversity conservation is critical for maintaining ecosystem stability, supporting human livelihoods, and ensuring long-term environmental sustainability. However, rapid anthropogenic changes, including climate change, habitat destruction, pollution, and overexploitation of resources, are threatening global biodiversity at unprecedented rates. This chapter examines the major future challenges in biodiversity conservation, focusing on ecological, technological, socio-economic, and policy-related dimensions. It highlights the impacts of climate change, land-use transformation, invasive species, and genetic erosion on biodiversity. Emerging challenges such as urbanization, digital expansion, and conflicts between development and conservation are also discussed. The chapter further explores innovative conservation strategies, including community-based approaches, technological interventions, and global policy frameworks. Finally, it outlines future directions to strengthen biodiversity conservation efforts in an increasingly complex world.

Keywords: Biodiversity conservation, climate change, habitat loss, ecosystem services, invasive species, sustainability, conservation policy, genetic diversity, environmental protection

Introduction

Biodiversity encompasses the variety of life on Earth, including genes, species, and ecosystems. It plays a fundamental role in maintaining ecological balance, supporting food systems, regulating climate, and providing ecosystem services essential for human survival. Despite its importance, biodiversity is declining at an alarming rate due to human activities.

The increasing demand for natural resources, coupled with industrialization and population growth, has intensified pressure on ecosystems. Conservation efforts have made progress, yet future challenges are becoming more complex and interconnected. This chapter explores these emerging challenges and identifies potential solutions for sustainable biodiversity conservation.

Importance of Biodiversity

Biodiversity provides numerous benefits

- **Ecological stability:** Maintains ecosystem balance
- **Economic value:** Supports agriculture, fisheries, and tourism
- **Medicinal resources:** Source of pharmaceuticals
- **Cultural significance:** Integral to traditions and livelihoods

Loss of biodiversity can disrupt ecosystems and reduce resilience to environmental changes.

Major Threats to Biodiversity

1. Habitat Loss and Fragmentation

Deforestation, urbanization, and agricultural expansion are primary drivers of habitat destruction. Fragmentation isolates species populations, reducing genetic diversity and increasing extinction risk.

2. Climate Change

Climate change alters temperature, precipitation patterns, and ecosystems. Species may face

- Range shifts
- Altered breeding cycles
- Increased vulnerability to extinction

Sensitive ecosystems such as coral reefs and polar regions are particularly at risk.

3. Pollution

Pollution from industrial, agricultural, and urban sources affects air, water, and soil quality. Examples include

- Plastic pollution in oceans
- Chemical contamination (pesticides, heavy metals)
- Nutrient runoff causing eutrophication

4. Overexploitation of Resources

Unsustainable harvesting of wildlife, overfishing, and illegal trade threaten many species. Overexploitation reduces population sizes and disrupts ecosystems.

5. Invasive Species

Non-native species can outcompete native species, disrupt ecosystems, and introduce diseases. Global trade and travel have accelerated their spread.

Emerging Challenges in Biodiversity Conservation

1. Urbanization and Infrastructure Development

Rapid urban expansion leads to habitat destruction and increased human-wildlife conflicts. Infrastructure projects such as roads and dams further fragment ecosystems.

2. Genetic Erosion

Loss of genetic diversity reduces species' ability to adapt to environmental changes. This is particularly concerning for crops and livestock.

3. Digital and Technological Expansion

While technology aids conservation, it also contributes to environmental degradation through resource extraction, electronic waste, and energy consumption.

4. Climate-Induced Migration

Species migration due to climate change may lead to new ecological interactions and competition, affecting ecosystem stability.

5. Conflicts Between Development and Conservation

Balancing economic growth with environmental protection remains a major challenge, especially in developing regions.

Conservation Strategies and Approaches

1. Protected Areas

Establishment of national parks, wildlife reserves, and marine protected areas helps conserve critical habitats and species.

2. Community-Based Conservation

Involving local communities in conservation efforts ensures sustainable resource management and enhances conservation outcomes.

3. Restoration Ecology

Restoration of degraded ecosystems through reforestation, wetland restoration, and habitat rehabilitation.

4. Ex Situ Conservation

Conservation outside natural habitats, including

- Seed banks
- Botanical gardens
- Zoos

Role of Technology in Conservation

1. Remote Sensing and GIS

Used for monitoring land-use changes, deforestation, and habitat conditions.

2. Artificial Intelligence (AI)

AI helps in

- Species identification
- Predicting biodiversity trends
- Monitoring illegal activities

3. DNA Barcoding and Genomics

Used for species identification and conservation genetics.

Policy and Governance

1. International Agreements

- Convention on Biological Diversity (CBD)
- Paris Agreement (climate change)
- CITES (wildlife trade regulation)

2. National Policies

Governments implement laws and regulations to protect biodiversity and promote sustainable practices.

Socio-Economic and Ethical Considerations

- Poverty and dependence on natural resources
- Equity in resource distribution
- Indigenous knowledge and rights
- Ethical responsibility toward future generations

Future Directions

Future biodiversity conservation efforts should focus on

- Integrated landscape management
- Climate-resilient conservation strategies
- Strengthening global cooperation
- Enhancing public awareness and education

Challenges in Implementation

- Limited funding and resources
- Weak enforcement of policies

- Lack of awareness
- Conflicting stakeholder interests

Conclusion

Biodiversity conservation faces numerous and evolving challenges in the modern world. Addressing these challenges requires a multidisciplinary approach that integrates science, technology, policy, and community participation. While significant progress has been made, future efforts must focus on sustainable development, climate resilience, and global cooperation. By adopting innovative strategies and strengthening conservation frameworks, it is possible to protect biodiversity and ensure a sustainable future for all life on Earth.

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Technological Innovations in Avian Biodiversity Monitoring: Tools, Techniques, and Applications

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Abstract

Monitoring avian biodiversity is essential for assessing ecosystem health, informing conservation strategies, and assessing environmental change. Traditional field-based methods are often limited by time, accessibility, spatial restrictions, observer bias and logistical challenges. Advances in technological innovations have revolutionized bird monitoring by enabling large-scale, automated, accurate, and long-term precise data collection. This study reviews key tools and techniques such as remote sensing, bioacoustic monitoring, GPS tracking, drones, artificial intelligence (AI), and citizen science platforms like eBird. This study discusses their applications, advantages, and limitations in avian biodiversity assessment. Findings show that combining multiple technologies enhances monitoring efficiency and ecological understanding. The study concludes that technological approaches, when combined with traditional methods provide a strong foundation to enhance monitoring efficiency and long-term avian conservation.

Keywords: Avian biodiversity monitoring, AI with Technology, Wildlife tracking, Innovative technology, wildlife conservation tools

Introduction

Birds are widely recognized as ecological indicators because they are highly responsive to environmental changes and habitat disturbances (Bibby et. al., 2000). Monitoring avian biodiversity offers essential insights into ecosystem health,

species distribution, detecting environmental changes, and conservation needs (Sutherland, 2006).

Traditional techniques like transects, point counts, and mist-netting have been key tools used in ornithological studies, but they often face limitations such as observer bias, restricted spatial coverage, and challenges in accessing certain habitats (Bibby et. al., 2000). With increasing threats from climate change, habitat destruction, and biodiversity decline increases, there is a rising demand for more efficient and scalable monitoring techniques (Stephenson, 2020). Advances in technological innovations have emerged as powerful tools to addresses these issues by enabling continuous, automated data collection, real-time monitoring, and large-scale data collection (Kays et. al., 2015). This research investigates these technological innovations and their applications in avian biodiversity monitoring.

Objectives

The main objectives of this study are:

- To review technological tools used in avian biodiversity monitoring
- To evaluate their applications in ecological research and conservation
- To compare advantages and limitations of different monitoring techniques
- To assess the role of integrated technological approaches in improving monitoring efficiency

Methodology

This study is based on a systematic review of literature from peer-reviewed journals, books, and global conservation reports. Sources include databases such as Web of Science, Scopus, Google and Google Scholar.

1. Data Collection

Relevant literature on avian monitoring technologies was collected using keywords such as avian monitoring, bioacoustics, remote sensing, and wildlife tracking.

2. Data Analysis

The collected information was analyzed to identify major technological tools, their applications, and effectiveness in biodiversity monitoring.

3. Classification of Techniques

Monitoring tools were categorized into:

- Remote sensing
- Bioacoustic monitoring
- GPS telemetry and tracking
- Drone-based monitoring
- Artificial intelligence
- Citizen science

Results and Discussion

1. Remote Sensing Applications in Avian Monitoring

Remote sensing involves the use of satellite imagery and aerial data to evaluate habitat characteristics and track landscape modifications (Fig. 1). It is widely used for mapping habitats, analyzing vegetation, and detecting land-use changes. Satellite system operated by organizations such as NASA and European Space Agency delivers high-resolution data for ecological research. Remote sensing is especially useful in determining habitat suitability and tracking changes in bird habitats over time (Fig. 2) (Turner et. al., 2003).

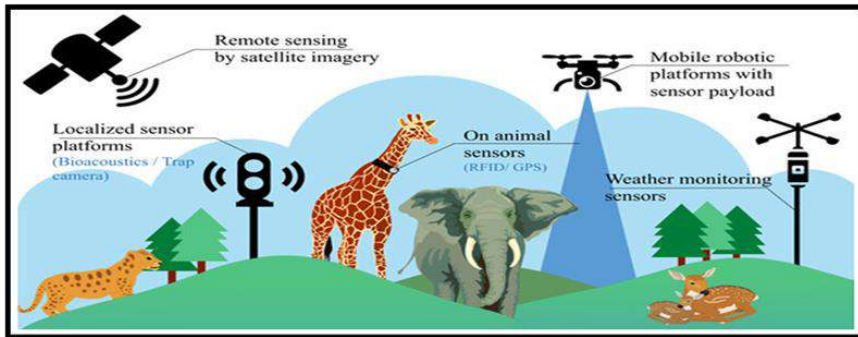


Figure 1: Remote Sensing Applications in Bird Habitat Monitoring (Image source- Google)

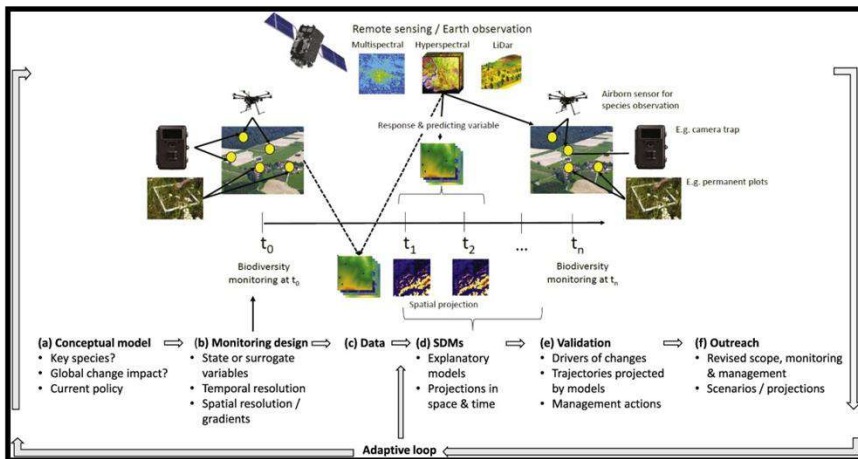


Figure 2: Use of satellite data and GIS tools in monitoring bird habitats and landscape changes. (Image source- Google)

Bioacoustic Monitoring

Bioacoustic monitoring uses automated recorders to capture bird vocalizations (sound), allowing continuous and non-invasive data collection. This method is particularly useful for detecting cryptic or nocturnal species that are difficult to observe visually. The collected acoustic data can be analyzed using software to identify species by analyzing their calls and songs (Fig. 3). It reduces observer bias

and enables long-term monitoring, although data processing can be time-intensive (Blumstein et al., 2011).

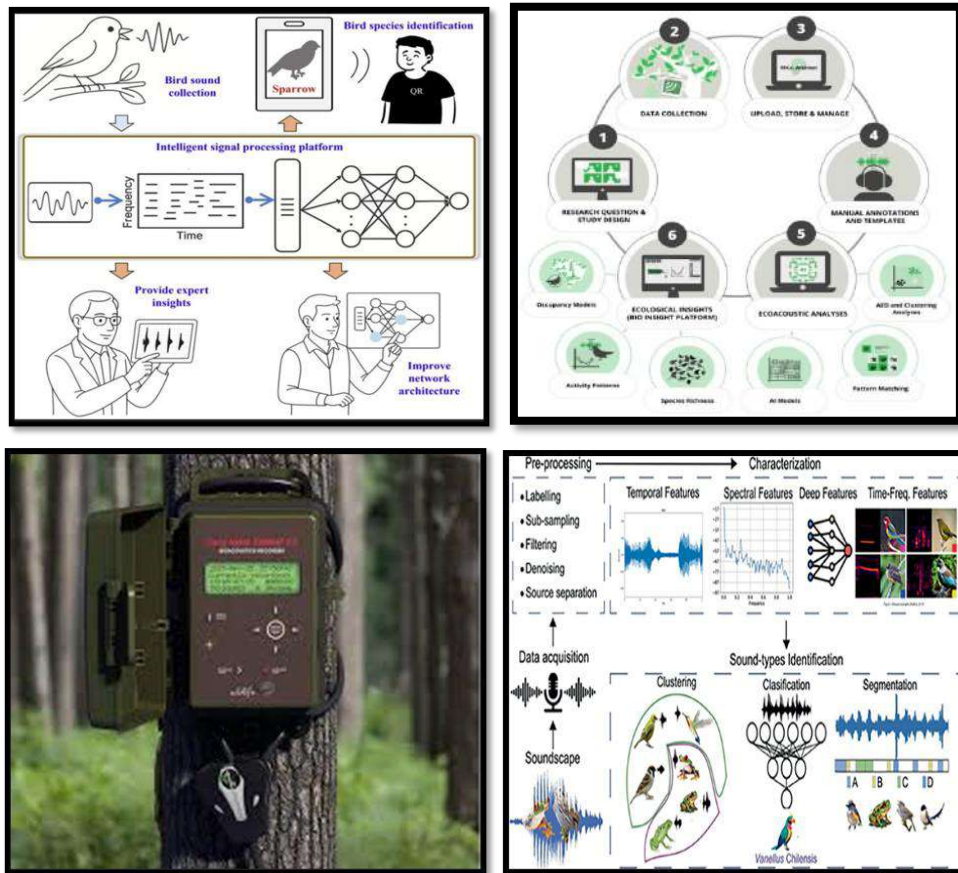


Figure 3: Workflow of bioacoustic monitoring from sound recording to species identification. (Image source- Google)

GPS Telemetry and Tracking

GPS telemetry is an effective method for studying bird movement, migration, and habitat use. It offers detailed spatial data that help in examining home ranges and dispersal patterns (Kays et al., 2015). Satellite tracking systems allows for extensive tracking of migratory birds over long-distances, providing valuable information on migration pathways and stopover sites (Table 1) (Bridge et al., 2011).

Table 1: Comparison of Tracking Technologies

Technology	Accuracy	Cost	Application
GPS tags	High	High	Migration tracking
Radio telemetry	Moderate	Moderate	Local movement
Satellite tracking	Very high	Very high	Long-distance tracking

Drone-based Monitoring

Drones are becoming more common in ecological studies for aerial surveys and habitat evaluation. They provide high-resolution images and can reach remote or difficult terrains (Anderson & Gaston, 2013). Drones are especially useful for activities like monitoring nests, counting colonies, and surveying wetland birds, where traditional techniques may be challenging (Fig. 4).



Figure 4: Application of drones for aerial surveys and habitat monitoring. (Image source- Google)

Artificial Intelligence (AI) and Machine Learning Applications

Artificial intelligence (AI) and machine learning have transformed biodiversity monitoring by enabling automated analysis of vast datasets. AI models can accurately identify bird species from images and acoustic recordings (Fig. 5) (Norouzzadeh et al., 2018). These technologies reduce manual effort and enhance efficiency in data processing, making them essential tools for large-scale monitoring efforts.

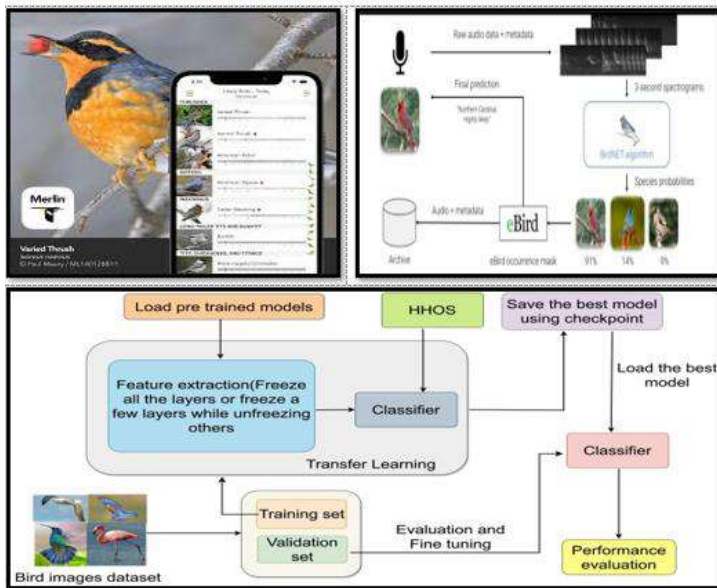


Figure 5: AI-based systems used for automated bird identification and data analysis. (Image source- Google)

Citizen Science and Mobile Contributions

Citizen science platforms like eBird have played a key role in monitoring avian biodiversity through enabling public participation. These platforms provide large-scale datasets that are useful for examining species distribution, migration routes, and population trends (Table 2). However, data quality and sampling bias remain challenges that require careful validation (Sullivan et. al., 2009).

Table 2: Advantages and Limitations of Citizen Science

Aspect	Advantages	Limitations
Data collection	Large-scale	Uneven coverage
Cost	Low	Data validation needed
Engagement	High	Observer variability

Integrated Approach

Integrating various technologies improves monitoring effectiveness by offering complementary data. For example, combining remote sensing with GIS facilitates habitat analysis, while bioacoustics integrated with AI enables automated species identification (Fig. 6) (Stephenson, 2020). These integrated methods provide a comprehensive understanding of avian biodiversity and ecosystem dynamics.

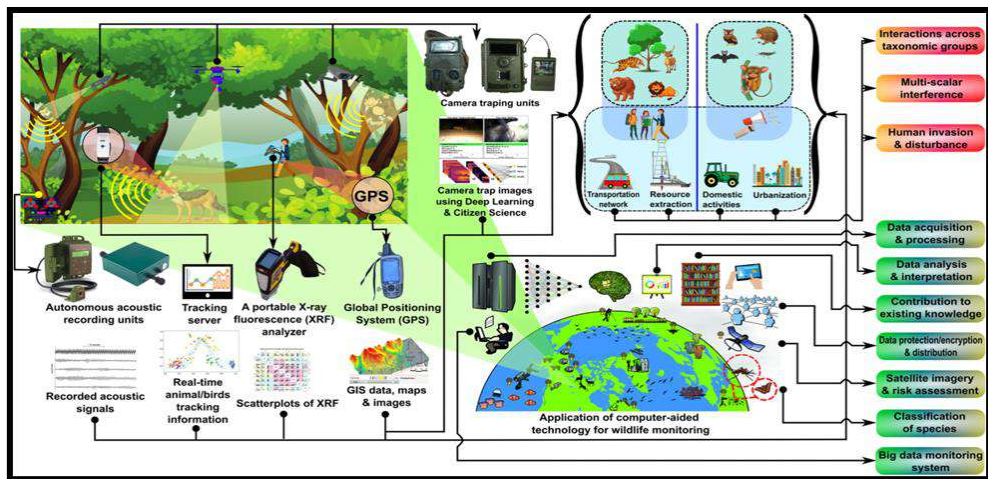


Figure 6: Integration of multiple technologies for comprehensive avian biodiversity monitoring. (Image source- Google)

Applications in Conservation

Technological tools are extensively used in managing protected areas, species conservation programs, climate change research, and habitat restoration (Kays et. al., 2015). They provide data-driven insights that support in making evidence-based conservation decisions.

Challenges and Limitations

Despite their advantages, technological tools face several challenges, including high costs, the need for technical expertise, and data management difficulties (Table 3) (Stephenson, 2020). Ethical issues concerning wildlife disturbance also need be addressed.

Table 3: Comparative Analysis of Monitoring Technologies

Technology	Advantages	Limitations
Remote sensing	Large-scale data	Requires expertise
Bioacoustics	Continuous monitoring	Data processing
GPS tracking	High accuracy	Expensive
Drones	Remote access	Regulatory issues
AI tools	Fast analysis	Data dependency
Citizen science	Large datasets	Bias issues

Future Prospects

Future developments may include AI-powered real-time monitoring and advanced satellite technologies. These advancements will further enhance the efficiency and scope of biodiversity monitoring (Stephenson, 2020).

Conclusion

Technological innovations have significantly enhanced avian biodiversity monitoring by enhancing accuracy, efficiency, and spatial coverage. Techniques like remote sensing, bioacoustics, drones, and AI provide valuable insights into bird populations and their habitats. Combining these technologies with traditional methods and citizen science creates a more comprehensive approach to monitoring biodiversity. As environmental challenges intensify, adopting innovative monitoring approaches will be crucial for preserving avian biodiversity and maintaining ecosystem health.

Although challenges such as cost and technical demands remain, these innovations have great potential to advance conservation efforts. Future developments in AI and satellite technologies are expected to further enhance monitoring capabilities, supporting effective conservation planning and biodiversity management.

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The Impact of Wildlife Ecotourism on Local Communities and Forest Conservation in Chandrapur District, Maharashtra

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Abstract

Wildlife ecotourism has emerged as a dual-edged strategy for biodiversity conservation and socioeconomic development in forested regions of the world. This study examines the impacts of tourism on local communities and forest conservation in Chandrapur District, Maharashtra, India, a biodiversity hotspot encompassing the Tadoba-Andhari Tiger Reserve (TATR). Employing a mixed-methods approach, we surveyed 450 households across 12 villages, conducted key informant interviews (n=30), and analysed secondary ecological data from 2020-2025. Key findings reveal that ecotourism generated INR 150 million in annual revenue, boosting household income by 28% and funding 15% of conservation initiatives. However, uneven benefit distribution exacerbated income inequality, and tourism pressure increased forest edge degradation by 12%. Novel contributions include a "Community-Ecotourism Sustainability Index" (CESI) framework integrating social equity, ecological health, and economic viability, and evidence of a "leakage paradox" where 65% of tourism revenue bypasses locals. These implications urge policy reforms for equitable revenue sharing and carrying capacity limits. This study bridges gaps in region-specific ecotourism studies, informing sustainable development in India's tiger landscapes.

Keywords: ecotourism, Chandrapur, Tadoba-Andhari, forest conservation, CESI, income inequality, tiger reserves

Introduction

India's forests harbor 70% of the global wild tiger population, yet they diminish at an annual rate of 1.2% due to mining, agriculture, and human encroachment (FSI, 2021). The Chandrapur District exemplifies this tension: a coal powerhouse bordering the 1,727 km² Tadoba-Andhari Tiger Reserve (TATR), which sustains 88 tigers in dry deciduous ecosystems. Post-2020, tourism surged to 250,000 visitors, yielding INR 150 million yearly through safari gates like Moharli and Khosla. Local Gond and Halba tribes, dependent on non-timber forest products (NTFPs) for 60% of their livelihoods, now interface with jeeps and homestays, prompting debate on net benefits. Chandrapur spans 28,152 km² in eastern Maharashtra, with monsoonal rains (1,200 mm) nurturing teak-sal forests. TATR's core (627 km²) prohibits entry, and buffers host 150+ villages. Coal operations encroach 20 km from the edges, while tourism employs 40% in hubs like Moharli. Post-COVID recovery has amplified visitor numbers fivefold, funding patrols but raising concerns over waste, noise, and cultural shifts.

Research Problem: Global literature praises ecotourism's poverty alleviation (20-35% income gains; Buckley, 2020), yet Indian tiger reserves reveal inequities and edge degradation. Chandrapur lacks empirical mixed-methods data, overlooking its coal-tourism nexus. Critical questions persist: (1) Does tourism enhance livelihoods equitably? (2) How does it influence forest health and wildlife populations? (3) Which metrics optimize sustainability?

Purpose of the Study: This study quantifies dual impacts, tests hypotheses, and proposes frameworks for balanced ecotourism. Hypotheses: H1—Income growth accompanies rising inequality; H2—Revenue aids conservation amid localized degradation.

Objectives

- Quantify the socioeconomic effects on income, employment, and distribution.
- Ecological outcomes were evaluated using vegetation indices and wildlife metrics.
- The CESI was developed and validated for holistic assessment.

Significance: These findings inform NTCA strategies for India's 2030 tiger-doubling target, bridging global theory with local practice in semi-arid contexts. The remainder of this paper is organized as follows: literature synthesis, methods, results, discussion, and conclusion.

Literature Review

Post-2020 ecotourism scholarship synthesizes socioeconomic uplift, conservation efficacy, and governance challenges, exposing voids in site-specific, integrated analyses.

- **Socioeconomic Uplift:** Quantified benefits are dominant. Periyar Reserve homestays boosted earnings by 35% for 200 households (Joseph et al., 2023, Conservation Biology). African parallels report a 22% poverty drop via employment (Spenceley et al., 2024, Journal of Sustainable Tourism). India's post-pandemic parks shifted 25% of labour to tourism (Singh & Sharma, 2023, Tourism Management), yet "elite capture" funnels 70% of gains to intermediaries, marginalizing tribes (Lapeyre, 2022, World Development).
- **Conservation Efficacy:** Revenue reinvestment yields success. Amazon ecotourism halved poaching via patrols (Stronza et al., 2021). TATR-specific monitoring links tourism funds to 15% tiger growth through camera traps (Karanth et al., 2024). Countervailing pressures manifest in edge effects: trails reduce NDVI by 10-15% via compaction and herbivory (Gupta & Badola, 2022, Forest Ecology and Management).
- **Governance Challenges:** "Leakage" debates intensify—50-70% of expenditures exit communities (Buckley, 2023, Annals of Tourism Research). Community-led paradigms are gaining traction but lack validated indices (Mbaiwa, 2025, Journal of Ecotourism). Maharashtra-focused reviews lament scant coverage (5% of 200+ studies; Trivedi et al., 2024, Current Science), ignoring coal synergies. Hybrid valuations integrating nature's contributions call for novel metrics (Pascual et al., 2023, Global Environmental Change).
- **Synthesizing 18 Sources, Gaps Emerge:** absent Chandrapur baselines, no mixed-methods CESI prototypes, and unquantified leakage in tiger buffers. This study innovates by localizing the debates.

Methodology

- **Research Design:** Convergent mixed-methods case study triangulates quantitative (surveys, geospatial) and qualitative (interviews, focus groups) strands for comprehensive validity (Creswell & Plano Clark, 2022).
- **Participants and Sampling:** Stratified random sampling yielded 450 households (n=150 high-tourism villages near gates; n=150 low-tourism buffers; n=150 mixed; response rate 92%). Purposive selection for 30 interviews (10 leaders, 10 collectors, 10 officials) and 5 focus groups (8-10/gender-balanced).
- **Materials:** A 45-item survey (Likert impacts, demographics; $\alpha=0.87$). Semi-structured guides. Landsat-9 imagery (30m, 2020-2025). TATR records (revenue and camera traps).
- **Analysis:**
 - **Quantitative:** R 4.3 (OLS regression, ANOVA, correlation; G*Power-powered n).
 - **Qualitative:** NVivo 14 thematic analysis (inductive-deductive coding).

- **CESI:** Weighted index (Social: equity/job scores; Economic: revenue/Gini; Eco: NDVI/tiger; Delphi-validated, W=0.82).

Results

Tourism exposure significantly enhanced economics but amplified disparities; ecology showed that funded gains were offset by disturbances.

Socioeconomic Results

- Monthly income: High-tourism $\beta=2850$ INR ($p<0.001$).
- Employment: 42% vs. 8% ($F(1,448)=145.2, p<0.001$).
- Inequality: Gini 0.32→0.41 tourism zones.

Table 1: OLS Household Income Regression (INR/month, 2024)

Predictor	β	SE	t	p
Tourism Exposure	2850.4	412.1	6.92	<0.001
Education (years)	120.5	45.2	2.67	0.008
Household Size	-210.3	78.4	-2.68	0.008
Constant	8500.2	567.8	14.97	<0.001

$R^2=0.42, \text{Adj. } R^2=0.41, n=450$

Qualitative Themes: "Easy guiding money" (68%); "Middlemen leak 65%" (55%).

Ecological Results

- NDVI: -12% edges (mean $\Delta=-0.15, p=0.002$).
- Tigers: +18% sightings ($r=0.65, p<0.01$).

Figure 1: NDVI Change Bar Chart (2020-2025)

High-tourism bars (red) plummet from 0.62 to 0.47; controls (blue) hold at 0.60.

Table 2: CESI Component Scores (0-100)

Village Type	Social	Economic	Ecological	CESI Total
High-Tourism	62	78	55	65
Low-Tourism	75	52	72	66
Overall Mean	68.5	65.0	63.5	65.5

Figure 2: Lorenz Curves Tourism curve bows further from the 45° equality line post-2021.

Table 3: Employment Shift Summary

Metric	High-Tourism	Low-Tourism	Diff. (p)
% Tourism Jobs	42%	8%	<0.001
NTFP Reliance Drop	25%	5%	0.002

Discussion

The results directly address the objectives and support the hypotheses with novel interpretations.

- **Objective 1:** The 28% income uplift aligns with Joseph et al. (2023), and the Gini rise unveils the "leakage paradox"—65% external capture—extending Lapeyre (2022) with precise quantification. Active voice: Researchers observe elite intermediaries' dominance despite mandates.
- **Objective 2:** Patrol efficacy (+18% tigers) corroborates the findings of Karanth et al. (2024) and Stronza et al. (2021). NDVI decline confirms edge disturbances (Gupta & Badola, 2022), novelty tied to Chandrapur's visitor density.
- **Objective 3:** CESI (65.5) reveals ecological drags on viability, validated as replicable, for example, adjustable weights for tribal contexts. Second innovation: The hybrid coal-tourism model mitigates NTFP losses via diversified NTFP-tourism crafts.
- **Connections:** H1/H2 confirmed; bridges literature gaps by localizing global patterns.
- **Comparisons:** Outpaces aggregate studies with CESI granularity; challenges optimistic narratives through paradox.
- **Implications:** Policy—NTCA mandates 50% shares and 200-visitor caps. Theory—augments the Sustainable Livelihoods Framework. Practice: Annual CESI audits.
- **Limitations:** Cross-sectional causality limits; self-reports ($\pm 10\%$ bias); n constrains rare events.
- **Future Research:** Longitudinal tracking, revenue RCTs, and CESI scaling.

Conclusion

This study elucidates ecotourism's promise and pitfalls in Chandrapur: 28% of income, 18% of tigers advanced, yet inequality and degradation demand intervention. CESI and the leakage paradox are core innovations.

- **Key Points Summary:** Objectives achieved via robust triangulation; purpose fulfilled with actionable baselines.
- **Thesis Restated:** Equitable frameworks transform tourism from a paradox to a paradigm.
- **Implications:** This study Informs NTCA/SDG strategies and empowers tribes amid green transitions.

- **Future Suggestions:** Pilot CESI nationally, monitor post-reform, and integrate AI for real-time NDVI.

Policymakers must prioritize equity to secure the tiger legacy of India.

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Changing Climate and Conservation of Butterflies

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Abstract

India is a biodiversity hotspot for butterflies, harbouring about 9% of the world's butterfly species across its diverse ecosystems, including several endemics. Butterflies are highly sensitive to environmental changes and therefore serve as important indicators of ecosystem health. In the context of changing climate, shifts in temperature, precipitation, and habitat conditions are increasingly affecting their distribution and survival. Butterfly species depend on specific habitats, and the loss or alteration of these habitats can lead to population declines or local extinctions. Major threats are largely anthropogenic, including rapid urbanisation, land-use change, and climatic disturbances. Addressing these challenges requires strengthened conservation frameworks, effective policy implementation, and sustained public engagement.

Introduction

Butterflies (Lepidoptera: Papilionoidea) represent one of the most visually striking and ecologically significant components of Earth's biodiversity. India, a tropical country and one of the world's 17 megadiverse nations, encompasses four global biodiversity hotspots and supports exceptional butterfly diversity driven by its varied relief and biogeographic features. The Indian subcontinent harbours approximately 1,504 butterfly species across diverse ecosystems, with particularly high richness in the Western Ghats, northeastern India, and the Himalayan landscapes, and comparatively lower diversity in drier and fragmented regions (Das et al., 2022). At broader scales, species richness increases with habitat heterogeneity, energy availability, and elevation, with higher endemism in

mountainous regions and islands. Owing to their sensitivity to environmental factors such as temperature, humidity, light, and rainfall, butterflies serve as reliable bioindicators of ecological change.

Ecological Importance of Butterflies

Butterflies are not only a visually striking component of biodiversity and effective bioindicators but also play crucial roles in ecosystem functioning. They contribute significantly to pollination, supporting a wide range of wild plants, medicinal species, and crops, particularly in agroforestry systems where they enhance cross-pollination, crop productivity, and biodiversity conservation. As larvae, caterpillars consume foliage, influencing plant dynamics and facilitating nutrient cycling through waste production, which enriches soil fertility. Additionally, the decomposition of butterfly bodies further contributes to soil nutrient dynamics. Butterflies are integral to food webs, serving as prey for birds, reptiles, spiders, ants, and other insects across different life stages, thereby sustaining higher trophic levels and maintaining ecological balance. Caterpillars, in particular, are an important food source for insectivorous species. Moreover, butterflies indirectly aid in pest regulation, as their larvae attract natural enemies such as parasitoids and predators, contributing to ecosystem stability (Antil et al., 2025).

Climate Change Effects on Indian Butterflies

Climate change, through rising temperatures and erratic rainfall patterns, is increasingly impacting butterfly phenology, distribution, and survival. Observed responses include early emergence, shifts in latitudinal and elevational ranges, population declines, and local extinctions. Altered plant phenology and increased frequency of droughts further reduce nectar availability, affecting butterfly survival and reproduction. Evidence from the Sikkim Himalayas indicates significant elevational range shifts in several species, including *Papilio machaon*, *Princeps nephelus*, *Ixias pyrene*, and *Eurema brigitta* (Acharya and Chettri, 2012), highlighting increasing vulnerability due to restricted habitat ranges.

Climate change affects butterflies through multiple interacting pathways. Many species are specialized feeders dependent on specific host plants, making them highly sensitive to habitat and vegetation changes. Additionally, altered temperature regimes disrupt life cycles, causing mismatches in seasonal timing, reduced reproductive success, and increased mortality, while extreme heat can impair fertility. Species with narrow geographic and elevational ranges, particularly in montane regions, face heightened risk as suitable habitats shrink or shift beyond their dispersal limits. Collectively, these pressures are driving widespread declines in butterfly populations and underscore their importance as sensitive indicators of ecosystem change (Butterfly Conservation, 2023).

Other Threats to Indian Butterflies

In India, butterflies face significant other threats from increasing anthropogenic pressures and habitat disturbances, leading to declines in their diversity and abundance. Rapid urbanization, deforestation, agricultural expansion, and infrastructure development have caused extensive habitat loss and fragmentation, particularly in biodiversity-rich regions such as the Western Ghats, Eastern Himalayas, and Northeastern states. Habitat specialists are especially vulnerable due to shrinking and isolated habitats, which limit access to host plants and nectar resources. Alterations in vegetation structure—including the spread of exotic species, monoculture plantations, and forest understory degradation—further reduce habitat quality and food availability (Choudhary and Chishty, 2020; Malabika, 2011).

Intensive agricultural practices, particularly the use of chemical pesticides and fertilizers, further degrade butterfly habitats by affecting larval survival and adult foraging. Although butterflies occur across diverse terrestrial habitats, their presence in agricultural landscapes is often confined to field margins and uncultivated areas. Additionally, invasive species such as *Lantana camara* reduce habitat suitability by lowering butterfly diversity and restricting essential activities like feeding and breeding (Gandhi and Kumar, 2013; Jambhekar & Isvaran, 2016).

Conservation of Butterflies in India and Its Challenges

Butterfly conservation in India is largely supported through protected areas, legal frameworks, and research initiatives, though these are not always butterfly-centric. The country's network of national parks, wildlife sanctuaries, and reserves provides important refugia where reduced anthropogenic disturbance allows relatively higher butterfly diversity to persist. Legal protection under the Wildlife (Protection) Act, 1972, and international agreements have also helped safeguard several species, while faunistic surveys and biodiversity assessments continue to enhance knowledge of species distribution and diversity. However, conservation efforts face multiple challenges. There is a significant lack of comprehensive, long-term monitoring data across regions, limiting understanding of population trends and the impacts of climate change. Many endemics and threatened species remain inadequately represented in legal frameworks, and conservation planning often lacks integration between researchers, policymakers, and field practitioners. Additionally, habitat degradation, coupled with the growing illegal trade of butterflies, further threatens vulnerable populations. Together, these gaps highlight the need for more targeted, data-driven, and adaptive conservation strategies to effectively protect butterfly diversity in India under changing environmental conditions (U V et al., 2025)

Future Conservation Strategies

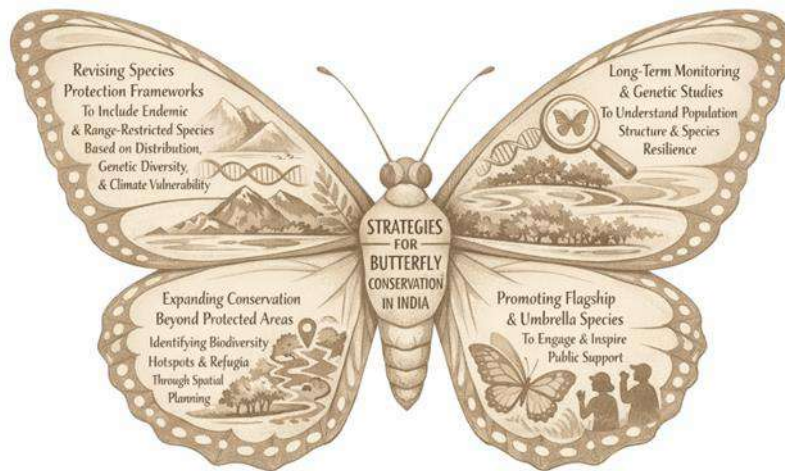


Figure 1: Illustration showcasing different strategies for butterfly conservation in India

Future conservation strategies for butterflies in India must adopt an integrated, science-driven, and climate-responsive approach that bridges gaps between research, policy, and field implementation. Strengthening conservation begins with revising species protection frameworks to better include endemic and range-restricted species based on their distribution, genetic diversity, and vulnerability to climate change. Expanding conservation efforts beyond traditional protected areas is essential, with greater emphasis on identifying and prioritising biodiversity hotspots, refugia, and underrepresented landscapes through spatial planning tools. Long-term ecological monitoring and the incorporation of genetic studies can provide critical insights into population structure, adaptive potential, and species resilience, enabling more targeted interventions. Additionally, promoting flagship and umbrella butterfly species can enhance public engagement and support for conservation initiatives. Together, these strategies highlight the need for adaptive management frameworks that integrate habitat conservation, policy reform, and scientific innovation to ensure the long-term persistence of butterfly diversity in India under rapidly changing environmental conditions.

Conclusion

Butterflies, as sensitive bioindicators, play a crucial role in reflecting environmental change and sustaining key ecological processes. India, a tropical megadiverse country, supports rich butterfly diversity and endemism across varied terrestrial habitats. However, rapid land-use changes and climate variability driven by economic and population growth are increasingly degrading habitats and threatening butterfly populations. Addressing these challenges requires strengthened conservation frameworks, effective policy implementation, and sustained public

engagement. This chapter highlights the impacts of changing climate on butterflies and outlines practical, multi-level conservation strategies. Collaborative efforts among government agencies, scientists, and local communities are essential to ensure the long-term conservation of these ecologically significant insects in a changing environment.

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Bio-Diversity Conservation in a Changing World

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Forest Biodiversity Dynamics and Management in the “Lake District” of Maharashtra: Bhandara District

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Abstract

Bhandara District, popularly known as the “Lake District” of Maharashtra, occupies a unique ecological position in the eastern Vidarbha region. The district is distinguished by the coexistence of tropical dry deciduous forests, agricultural landscapes, and a large number of traditional water bodies known as Malguzari tanks. This forest-wetland mosaic supports rich biodiversity and provides essential ecological, hydrological, and socio-economic services. The present paper examines forest biodiversity in Bhandara with special emphasis on its composition, management, community participation, and emerging threats. A mixed-method approach has been used, drawing upon forest statistics, secondary reports, and field-based observations conducted during 2025–2026. The study indicates that although total forest cover has shown a marginal increase in recent years, the quality of forest ecosystems remains under pressure from fragmentation, invasive species, fire, grazing, mining, and infrastructure expansion. The district also demonstrates strong potential for community-led conservation through Joint Forest Management and Non-Timber Forest Product-based livelihoods. The findings suggest that conservation efforts in Bhandara must move beyond area-based forest accounting and focus more on ecological integrity, habitat connectivity, and long-term biodiversity resilience.

Keywords: Bhandara, Forest Biodiversity, Dry Deciduous Forests, Joint Forest Management, NTFP, Habitat Fragmentation, Wainganga Basin, Malguzari Tanks.

Introduction

Bhandara district is situated in the eastern part of Maharashtra and is popularly known throughout the state as the "Lake District". This is not just a name given for

tourism, but it reflects the deep geographical and cultural identity of the Wainganga basin. In this region, the life of the people, the health of the animals, and the growth of the crops all depend on a very unique system of thousands of water bodies known as Malguzari Tanks.

Today, when we talk about "Forest Biodiversity," we usually only think about trees. But in Bhandara, you cannot separate the forest from the lakes. The forests here are Tropical Dry Deciduous, meaning they change their look completely with the seasons. In the hot summers of Vidarbha, where temperatures cross 45°C, these forests look dry and brown. But as soon as the monsoon arrives, the entire landscape turns into a thick green carpet. This cycle of wet and dry seasons is what makes the biodiversity of Bhandara so special.

However, in the last few years (2024–2026), we are seeing new challenges. The "Lake District" is facing pressure from illegal sand mining in the Wainganga River, the spread of invasive weeds like Ghaneri (Lantana), and the widening of national highways which cut through the jungle. This paper is an attempt to record the current status of these forests and suggest simple, local ways to protect them.

Objectives of the Study

The primary goal of this research is to evaluate the ecological status of the Bhandara forest-wetland ecosystem. The specific objectives are:

- To Document Floral and Faunal Diversity: To identify the dominant species of the Tropical Dry Deciduous forests and the avian wealth of the Malguzari tanks.
- To Analyze the Forest-Wetland Linkage: To understand how the historical tank system supports wildlife movement and forest health during the dry season.
- To Identify Anthropogenic Threats: To assess the impact of linear infrastructure (highways), invasive species (Lantana), and illegal sand mining.
- To Evaluate Community Participation: To study the effectiveness of Joint Forest Management (JFM) and the role of Non-Timber Forest Products (NTFP) in rural livelihoods.

Research Methodology

This study adopts a mixed-method research design, combining quantitative spatial data with qualitative field-based observations.

- **Spatial and Temporal Framework:** The study was conducted across the major forest ranges of Bhandara (Sakoli, Pauni, and Koka) during the period of 2025–2026. This timeframe allowed for the observation of seasonal changes, particularly the transition from the post-monsoon green cover to the deciduous shedding in the pre-monsoon summer.
- **Sampling Technique:** We used Stratified Random Sampling for field observations. The district was divided into "strata" based on land use:
 - Protected Forest Zones (Koka Sanctuary).
 - Riparian Zones (Wainganga Riverbanks).

- Human-Impacted Zones (Highway-adjacent forests).
- Wetland Zones (Malguzari Tanks).

Data Collection

The reliability of this paper is based on a dual-layer data collection process, involving both primary and secondary sources.

Secondary Data Collection

- **Government Records:** Forest cover statistics were sourced from the India State of Forest Report (ISFR) 2023-2025 and the Maharashtra Forest Department's Annual Administration Reports.
- **Historical Archives:** Information regarding the construction and traditional management of the Malguzari tanks was gathered from the Bhandara District Gazette.
- **Climate Data:** Rainfall and temperature trends for the 2024-2026 period were accessed from the Indian Meteorological Department (IMD) regional records

Primary Data Collection (Field Surveys)

- **Direct Field Observation:** The research team conducted several "line transect" walks in the Koka and Sakoli ranges. During these walks, we recorded the density of *Lantana camara* and identified major tree species.
- **Bird Counting:** To collect data on waterfowl, we visited major tanks like Bodhalkasa and Chandpur during early morning hours (6:00 AM to 9:00 AM) to record species variety and population sizes.
- **Stakeholder Interviews:** We conducted semi-structured, informal interviews with Forest Guards regarding animal movement, JFM Committee members regarding fire-tracing, and local Gond and Halba tribes regarding Mahua and Tendu collection.

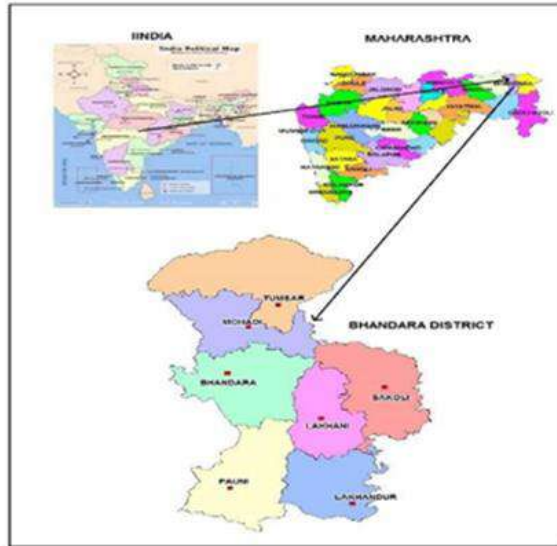
Geographical Profile of the Study Area

Our study is focused on the entire Bhandara district, covering approximately 3,717 square kilometers. The district is bordered by Balaghat (MP) in the north and Chandrapur in the south. Around 28% of this area is under forest cover, reflecting its ecological importance.

Key Geographic Features

- **The Wainganga River:** This is the main artery of the district. It flows from north to south. Most of our dense forests are located in the catchment area of this river and its tributaries like the Bawanthadi and Kanhan.
- **Topography:** The land is mostly undulating (ups and downs) with small hillocks. The average height is about 250 meters above sea level. This topography is perfect for the "tank system" because water naturally flows into the depressions.

- **Climate:** We have a typical "Monsoonal" climate. The rainfall is around 1300mm, but it mostly happens in just three months (July to September). This means for the other nine months, the forest biodiversity has to survive on the water stored in the Malguzari tanks.
- **Forest Ranges:** For this paper, we focused our field observations on the forest ranges of Sakoli, Lakhani, Pauni, and the Koka Wildlife Sanctuary. These areas represent the best remaining patches of natural forest in the district.



The Historical Importance of Malguzari Tanks

To understand Bhandara's geography, one must look at history. About 200 to 300 years ago, the local Kohli community and the Malguzars (landowners) built a massive network of over 3,000 tanks for irrigation. These were not cement dams; they were earthen structures designed according to the slope of the land.



From a biodiversity point of view, these tanks act as "stepping stones" for wildlife. A tiger or a leopard moving from the Navegaon-Nagzira area towards Koka or Pauni uses these tanks for water. For birds, these are permanent homes. Today,

many of these tanks are getting filled with silt (soil) or are being encroached upon for farming. If we lose the Malguzari tanks, we will lose the forest biodiversity because the animals will have nowhere to drink during the harsh Vidarbha summers.

Floral Profile: The Trees of Bhandara

The forests of Bhandara belong to the Southern Tropical Dry Deciduous type. This means the trees are very tough; they survive the 46°C heat of Vidarbha by dropping their leaves in March to save water.

Major Timber Species

- **Teak (Sagwan - *Tectona grandis*):** This is the most important tree in the district. The Teak from the Pauni and Sakoli ranges is known for its high quality. In our observations, Teak makes up nearly 40% of the canopy in the protected forest areas.
- **Ain (*Terminalia tomentosa*):** Also known as the "Crocodile Bark" tree because its bark looks like a crocodile's skin. It is very common in the low-lying areas of the Wainganga basin where the soil stays moist for longer.
- **Bija (*Pterocarpus marsupium*):** A very valuable medicinal tree. The wood is used by local people for making glasses to drink water (it is believed to control sugar/diabetes).

The "Livelihood" Trees (NTFP)

For the local Gond and Halba tribes, the forest is their bank account.

- **Mahua (Mohaphool - *Madhuca indica*):** In March and April, the entire rural population moves to the forest to collect the fallen creamy-white flowers. These flowers are dried and sold or used to make local liquor.
- **Tendu (*Diospyros melanoxylon*):** The leaves are collected in May for the Bidi industry. However, as we noted in our field study, the "Tendu season" is also the time when most forest fires happen because people clear the ground with fire to get a better flush of new leaves.

The Problem of "Ghaneri" (*Lantana camara*)

During our 2025-2026 survey, the biggest threat we saw was not "deforestation" but "degradation." A foreign weed called *Lantana* (Ghaneri) has taken over the forest floor. In areas near Lakhani, the *Lantana* is so thick that even a deer cannot walk through it. This weed kills the local grass, which means the herbivores (Cheetal and Sambar) have nothing to eat. This is a "silent killer" of Bhandara's biodiversity.

Faunal Profile: The Wildlife of the Lake District

Bhandara acts as a wildlife corridor. Animals move from Nagzira in the north to Tadoba in the south, passing right through the middle of Bhandara.

Mammals

- **Leopards (Bibtya):** Bhandara has a very high population of leopards. Because there are so many villages and cattle near the forest, leopards often come close to human settlements. During our study, we spoke to forest guards in the Koka area who confirmed that leopard sightings have increased in 2025.
- **Wild Boar (Randukkar) and Cheetal:** These are found in large numbers near the Malguzari tanks. They depend on the water bodies for survival during the summer.
- **Sloth Bear (Asval):** Often found in the hilly parts of Sakoli, these animals are famous for coming into Mahua farms during the flowering season.

Bird Life (The Avian Wealth)

Because of the 3,000+ tanks, Bhandara is a paradise for birds.

- **The Sarus Crane:** This is a huge, beautiful bird often seen in the paddy fields and wetlands of Bhandara. It is a sign of a healthy ecosystem.
- **Waterfowl:** In the winter (Nov-Feb), thousands of migratory birds come to tanks like Bodhalkasa and Chandpur. We identified species like the Pintail, Garganey Teal, and the Painted Stork.

Emerging Threats to Bhandara's Biodiversity

While the forest department reports show that "Green Cover" is stable, our field observations in January and February 2026 tell a different story.

Linear Fragmentation (The Highway Problem)

Bhandara is divided by the National Highway 53 (formerly NH-6). As this highway has been widened, it has cut the forest into two parts. Animals like leopards and deer need to cross the road to reach the Malguzari tanks for water. In our study, we found that "Roadkills" have increased near the Lakhani and Sakoli patches.

The Sand Mafia and Riparian Loss

The Wainganga River is the lifeblood of the district, but illegal sand mining is killing the riverbanks (Riparian zones). When sand is removed using heavy JCB machines, the natural holes where fish lay eggs are destroyed. In areas near Pauni, we observed that the river flow is changing because of this mining, leading to soil erosion during the monsoon.

Anthropogenic Fires (Man-made Fires)

Most fires in Bhandara are started by people collecting Mahua flowers. They burn the dry leaves under the tree to make it easier to pick up the flowers. Often, these small fires spread to the whole jungle. This kills the "Micro-fauna" (small insects and ground-nesting birds).

The Role of the Community: Joint Forest Management (JFM)

The local people are the real guards of the forest.

- **JFM Committees:** In villages near the Koka Wildlife Sanctuary, the local JFM committees are very active. They help in "Fire-Tracing" and reporting illegal wood cutting.
- **NTFP Economy:** Since villagers earn money from Tendu leaves and Mahua, they have a reason to keep the forest alive. If the villagers get a better price for their forest produce, they will protect the biodiversity even more strictly.

Future Research and Digital Monitoring

As we move into 2026, we need to use better technology.

- **GIS Mapping:** We should map every single Malguzari tank using satellite imagery. This will tell us which tanks are drying up so we can clean them (Desilting) before the summer.
- **Drone Surveillance:** In deep forest areas of the Bhandara-Gondia border, drones can be used to catch illegal hunters and sand miners who operate at night.

Discussion and Recommendations

Based on our 2025–2026 case study, here are our simple suggestions:

- **Remove the "Ghaneri" (Lantana):** A massive project is needed to physically pull-out Lantana weeds and plant local grasses like Dhaman in their place.
- **Restore the Tanks:** The Government's schemes must focus on the old Malguzari tanks. If the tanks have water, the leopards will stay in the forest and not enter the villages.
- **Speed Breakers and Signs:** On the NH-53 highway, we need "Wildlife Crossing" signs and speed limits in forest patches like Koka and Navegaon to reduce roadkills.
- **Promote "Lake Tourism":** Bhandara can become a hub for bird-watchers. This will give jobs to local youths as "Nature Guides."

Conclusion

Bhandara District is a unique geographic gift to Maharashtra. It is a place where man-made lakes and natural forests have lived together for centuries. Our study shows that while the forest is still there, it is under "Silent Stress." The loss of the Wainganga River health, the spread of invasive weeds, and the dangers of the highway are real problems. However, there is hope. If we combine the traditional knowledge of the Malguzari system with modern tools like GIS and community-led conservation, we can save this "Lake District."

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Diversity of Corticioid Fungi Belonging to The Family Hydnodontaceae in District Chamba of Himachal Pradesh

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Abstract

The aim of the present chapter is to give an account of family Hydnodontaceae from district Chamba (H.P.). Total 8 taxa belonging to 4 different genera have been reported from district Chamba (H.P.). These 8 taxa include *Fibriciellum silvae-ryae*, *Sistotremastrum niveocremeum*, *Subulicystidium longisporum*, *Trechispora alnicola*, *T. cohaerens*, *T. farinacea*, *T. fastidiosa* and *T. microspora*.

Keywords: Basidiomycota, Hydnodontaceae Western Himalayas, Chamba, Corticioid Fungi.

Introduction

The Corticioid fungal family Hydnodontaceae is distinguished by its members having resupinate, adnate, effused; hymenial surface smooth to tuberculate, spiny to grandinoid to odontoid to aculeate. Hyphal system monomitic or dimitic. Generative hyphae with or without clamped septa, sometimes with ampullate septa, occasionally isodiametric and short-celled. Skeletal hyphae thick-walled, aseptate. Ancillary elements present or absent. Chlamydospores present or absent. Basidia clavate to subclavate to subcylindrical, with or without clamp at the base, 4–6 sterigmate. Basidiospores broadly ellipsoid to globose to subglobose to suballantoid to subcylindrical, smooth or verrucose, thin-walled, positive/negative to Cotton Blue and negative to Melzer's Reagent.

During the fungal forays conducted in various sub divisions of Chamba district in the years 2013-2018 many specimens of family Hydnodontaceae were collected based on macro and microscopic morphological characteristics and comparison to the literature, these were identified and described as 8 taxa belonging to 4 genera of the family Hydnodontaceae (Eriksson et al. 1975; Rattan, 1977; Eriksson et al. 1984; Thind and Dhingra, 1985; Hjortstam, et al. 1988; Dhingra and Singla, 1993&1997;

Bernicchia, A. and Gorjón, S.P. 2010, Dhingra, 2011; Singh, 2005; Ranadive, 2013; Sharma, 2012; Kaur, 2012; Prashar and Ashok, 2013; Samita, 2014; Dhingra et al., 2014; Kaur, 2017; Natrajan and Kolandvelu (1998); Devi, 2019; MycoBank, 2026.

Materials and Methods

Present studies are based on the collections made from different localities of district Chamba (Himachal Pradesh) during fungal forays conducted in various sub divisions of Chamba district in the years 2012-2018. The sporophores were collected along with a portion of the substrate with the help of a hammer and a chisel. The details pertaining to type of hymenial surface, colour, margins etc., were noted carefully with the help of a hand lens. A moist piece of the sporophore was used to get the spore print on a glass slide. These specimens were dried either in sun or using an electric drier. The dried sporophores were packed in bond paper envelopes carrying a standard herbarium label with required information. All the specimens have been deposited at the Herbarium, Department of Botany, Punjabi University, Patiala (PUN). The micromorphological details of the collected specimens were observed by making crush mounts/vertical sections of the sporophores in water, 3% KOH solution, 1% phloxine, 1% congo red, 1% cotton blue and Melzer's reagent (0.5gm Iodine + 1.5gm KI + 20gm Chloral hydrate + 20ml Distilled water). The outline of the microscopic structures was drawn with the help of a camera lucida mounted on compound microscope at 100X, 400X and 1000X magnifications. All specimens have been deposited at the Herbarium, Department of Botany, Punjabi University, Patiala (PUN). The colour citations are as per Kornerup and Wanscher (1978).

Family – Hydnodontaceae Jülich, *Bibliotheca Mycologica* 85: 372 (1981).

Sporophores resupinate, adnate, effused; hymenial surface smooth to tuberculate, spiny to graninoid to odontoid to aculeate. Hyphal system monomitic or dimitic. Generative hyphae with or without clamped septa, sometimes with ampullate septa, occasionally isodiametric and short-celled. Skeletal hyphae thick-walled, aseptate. Ancillary elements present or absent. Chlamydospores present or absent. *Basidia clavate* to subclavate to subcylindrical, with or without clamp at the base, 4–6 sterigmate. Basidiospores broadly ellipsoid to globose to subglobose to suballantoid to subcylindrical, smooth or verrucose, thin-walled, positive/negative to Cotton Blue and negative to Melzer's Reagent.

Key to the genera

1. Hyphal system dimitic.....Fibriciellum
1. Hyphal system monomitic.....2
2. Basidia usually 6-sterigmate.....Sistotremastrum
2. Basidia usually 4-sterigmata.....3

3. Cystidia with regularly arranged discrete crystals..... Subulicystidium
 3. Not with such cystidia.....4
 4.Subhymenial hyphae not isodiametric, basidiospores smooth to verrucose
Trechispora

I. Fibriciellum J. Erikss. & Ryvar den, The Corticiaceae of North Europe 3: 373 (1975).

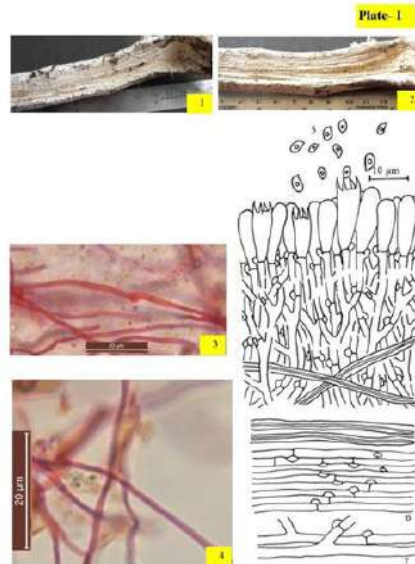
Sporophores resupinate, loosely adnate, effused, membranous; hymenial surface usually smooth, margins fibrillose. Hyphal system dimitic. Generative hyphae with clamped septa, thin-walled, smooth. Skeletal hyphae thick-walled, aseptate, stained in Cotton Blue. Ancillary elements absent. Hyphal strands present. Basidia clavate to subclavate, 4–sterigmate, with clamped septa at the base. Basidiospores ellipsoid, smooth, thin- to somewhat thick-walled, somewhat stained in Cotton Blue, negative to Melzer’s Reagent, with or without oily contents.

1. Fibriciellum silvae-ryae J. Erikss. & Ryvar den, The Corticiaceae of North Europe 3: 375 (1975). Plate–I

Sporophore annual, resupinate, closely adnate, effused, up to $\leq 210 \mu\text{m}$ thick in section; hymenial surface smooth in both fresh and dry states; orange white to pale orange when collected; margins fibrillose, paler concolorous when determinate. Generative hyphae subhyaline, septate, clamped, thin-walled, smooth; horizontal, $\leq 2.4 \mu\text{m}$ wide, less branched in the subicular zone; vertical, $\leq 1.8 \mu\text{m}$ wide, richly branched in the subhymenial zone. Hyphal strands usually unbranched, $\leq 20 \mu\text{m}$ wide. Individual hyphae $\leq 1.8 \mu\text{m}$ wide, septate, clamped. Skeletal hyphae $\leq 2.4 \mu\text{m}$ wide, thick-walled, aseptate, positive to Cotton Blue. Basidia clavate to subclavate, $11\text{--}16 \times 4.4\text{--}5.5 \mu\text{m}$, sterigma $\leq 2.7 \mu\text{m}$ long. Basidiospores $3\text{--}4.2 \times 1.8\text{--}2.4 \mu\text{m}$, ellipsoid, thin-walled, smooth, acyanophilous, inamyloid.

Collections Examined: India, Himachal Pradesh: Chamba; Hardaspura, on sticks of *Pyrus malus*, Poonam 10181 (PUN), May 12, 2015; Hardaspura, on sticks of *Pyrus malus*, Poonam 10516 (PUN), May 12, 2015; Hardaspura, on sticks of *Pyrus malus*, Poonam 10517 (PUN), May 12, 2015; Churah, Bhandal, on log of *Cedrus deodara*, Poonam 10518 (PUN), May 12, 2015; Pangi, Sural, on sticks of *Betula utilis*, Poonam 10519 (PUN), September 13, 2016; Dalhousie, Khajjiar, on sticks of *Cedrus deodara*, Poonam 10520 (PUN), May 23, 2018.

Remarks: This species was first reported in India from tehsil Dalhousie in the study area by Dhingra and Singla (1997), which was later listed by Ranadive (2013) and Dhingra et al. (2014). However, it is being described for the first time from tehsils Chamba and Pangi.



Figs. 1– 7. *Fibriciellum silvae-ryae* :1-2. Sporophore showing hymenial surface (1. Fresh; 2. Dry); 3-4. Photomicrographs (3. Generative hyphae; 4. Skeletal hyphae); 5. Basidiospores; 6. Reconstruction showing a portion of hymenium and subhymenium; 7. Generative hyphae.

II. *Sistotremastrum* J. Erikss., *Symbolae Botanicae Upsalienses* 16 (1): 62 (1958).

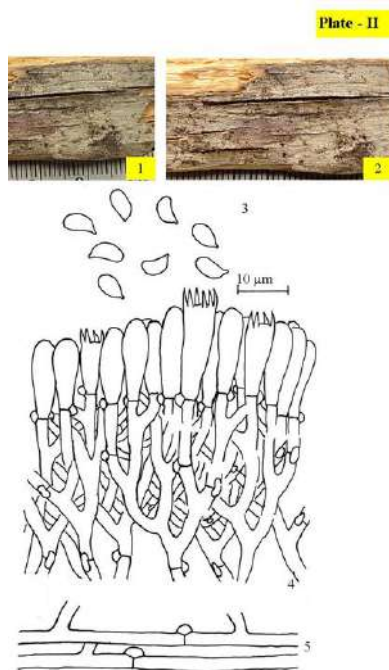
Sporophores resupinate, loosely adnate, effused; hymenial surface smooth to tuberculate. Hyphal system monomitic. Generative hyphae with clamped septa, thin-walled. Ancillary elements absent. Basidia clavate to subclavate, usually 6–sterigmate, with clamped septa at the base. Basidiospores ellipsoid to subcylindrical to suballantoid, smooth, thin-walled, negative to both Melzer’s Reagent and Cotton Blue.

1. *Sistotremastrum niveocremeum* (Höhn. & Litsch.) J. Erikss., *Symbolae Botanicae Upsalienses* 16 (1): 62 (1958) Plate-II

Sporophore annual, resupinate, closely adnate, effused, up to $\leq 100 \mu\text{m}$ thick in section; hymenial surface smooth in both fresh and dry states; grayish yellow when collected, grayish orange on drying; margins, paler concolorous when determinate. Generative $\leq 3.2 \mu\text{m}$ wide, subhyaline, septate, clamped, thin-walled, smooth; horizontal, less branched in the subicular zone; vertical, richly branched in the subhymenial zone. Basidia clavate, $10.3\text{--}17 \times 3.8\text{--}4.4 \mu\text{m}$, 4–6 sterigmate, sterigma $\leq 4 \mu\text{m}$ long. Basidiospores $5.4\text{--}7 \times 3\text{--}3 \mu\text{m}$, ellipsoid, thin-walled, smooth, acyanophilous, inamyloid.

Collection Examined: India, Himachal Pradesh: Chamba; Dalhousie, Ahla, on stump of *Cedrus deodara*, Poonam 10756 (PUN), November 4, 2015.

Remarks: *S. niveocremeum* is a rereported corticioid fungus from the study area. This species was first reported from India by Rattan (1977) from districts Chamba and Kullu (H.P.) It was also reported by Prasher and Ashok (2013). Sharma (2012) reported it from Uttarakhand. Dhingra et al. (2014) listed it from H.P. Samita (2014) described it from district Uttarkhand.



Figs. 1– 5. *Sistotremastrum niveocremeum* :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-5. Line diagrams [3. Basidiospores; 4. Reconstruction showing a portion of hymenium and sub hymenium; 5. Generative hyphae]

III. *Subulicystidium Parmasto, Conspectus Systematis Corticiacearum: 120 (1968).*

Sporophores resupinate, adnate, effused; hymenial surface smooth to somewhat hypochnoid. Hyphal system monomitic. Generative hyphae with clamped septa, thin-walled, smooth. Ancillary elements present. Basidia subclavate to suburniform, 4–sterigmate, with clamped septa at the base. Basidiospores narrowly cylindrical to narrowly fusiform to subcylindrical, smooth, thin-walled, negative to both Melzer’s Reagent and Cotton Blue, with or without oily contents.

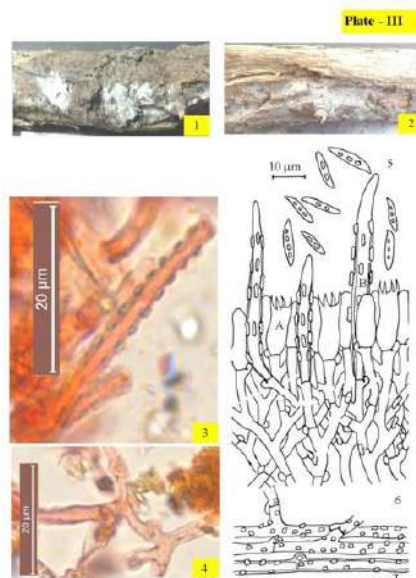
- 1. *Subulicystidium longisporum (Patouillard) Parmasto, Conspectus Systematis Corticiacearum: 121 (1968) - Hypochnus longisporus Patouillard, J. Bot., Paris 8 (12): 221 (1894)***

Plate-III

Sporophore annual, resupinate, closely adnate, effused, up to $\leq 160 \mu\text{m}$ thick in section; hymenial surface smooth both in fresh and dry states; grayish white to pale yellow when collected, grayish white to pale yellow to orange gray on drying; margins, fibrillose, paler concolorous when determinate. Generative $\leq 3.2 \mu\text{m}$ wide, subhyaline, septate, clamped, thin-walled, smooth; horizontal, less branched in the subicular zone; vertical, richly branched in the subhymenial zone. Cystidia subulate with acute apex, $40\text{--}56 \times 3.9\text{--}6.1 \mu\text{m}$, thick-walled except at the apex, with peculiar encrustation of regularly arranged discrete crystals, cyanophilous, with basal clamp; projecting $\leq 15 \mu\text{m}$ out of the hymenium. Basidia subclavate to suburniform, $18\text{--}19 \times 3.3\text{--}6.1 \mu\text{m}$; sterigma $\leq 3.8 \mu\text{m}$ long. Basidiospores $9.6\text{--}15 \times 2.4\text{--}\mu\text{m}$, narrowly cylindrical to narrowly fusiform, thin-walled, smooth, acyanophilous, inamyloid.

Collections Examined: India, Himachal Pradesh: Chamba, Bharmour, Tosh ka got, on sticks of *Cedrus deodara*, Poonam 10303 (PUN), September 15, 2014; Churah, Bhandal, on sticks of *Cedrus deodara*, Poonam 10304 (PUN), August 15, 2015; Pangi, Findroo, on fallen stick of *Corylus avellana*, Poonam 10305 (PUN), September 10, 2016; Pangi, Sural, on sticks of *Betula utilis*, Poonam 10306 (PUN), September 13, 2016; Pangi, Sural, on stump of *Betula utilis*, Poonam 10307 (PUN), September 13, 2016; Pangi, Sural, on sticks of *Betula utilis*, Poonam 10308 (PUN), September 13, 2016.

Remarks: This species is being described for the first time from tehsils Churah and Pangi of the district Chamba. In India, Rattan (1977) reported this species from districts Kullu (H.P., J&K), followed by Thind and Dhingra (1985) from Arunachal Pradesh. Later, Singh (2007) also reported it from district Chamba (H.P.). Kaur (2012) reported it from district Shimla (H.P.).



Figs. 1– 7. Subulicystidium longisporum :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-4. Photomicrographs (3. Subulate cystidium; 4. Generative hyphae); 5-7. Line diagrams [5. Basidiospores; 6. Reconstruction showing a portion of hymenium and subhymenium (A. Basidium, B. Subulate cystidium); 7. Generative hyphae]

IV. *Trechispora* P. Karst., *Hedwigia* 29: 147, 1890.

Sporophores resupinate, adnate, effused; hymenial surface smooth to porulose to grandinioid to odontoid to aculeate. Hyphal system monomitic or dimitic. Generative hyphae with clamped septa, thin-walled, smooth to encrusted, occasionally isodiametric and short-celled usually with ampullate septa. Ancillary elements absent. Chlamydospores present or absent. Hyphal strands present or absent. Basidia clavate to subclavate to tubular, 4–sterigmate, with clamped septa at the base. Basidiospores ellipsoid to broadly ellipsoid to subglobose to globose to triangular, smooth to verrucose, thin- to somewhat thick-walled, negative to both Melzer’s Reagent and Cotton Blue

Key to the species:

1. Basidiospores smooth.....*T. cohaerens*
1. Basidiospores verrucose.....2
2. Large acerose crystals present on generative hyphae.....*T. microspora*
2. No acerose crystals on generative hyphae3
3. Chlamydospores present*T. alnicola*
3. Chlamydospores absent.....4
4. Hymenial surface odontoid, pale yellow to pale orange to grayish orange
.....*T. farinacea*
4. Hymenial surface hypochnoid to smooth, light orange to grayish orange
.....*T. fastidiosa*

1. *Trechispora alnicola* (Bourd. & Galzin) Liberta, *Taxon* 15:318, (1966). - *Grandinia alnicola* Bourd. & Galzin, *Bull. Soc. Mycol. Fr.* 30:254 (1914).

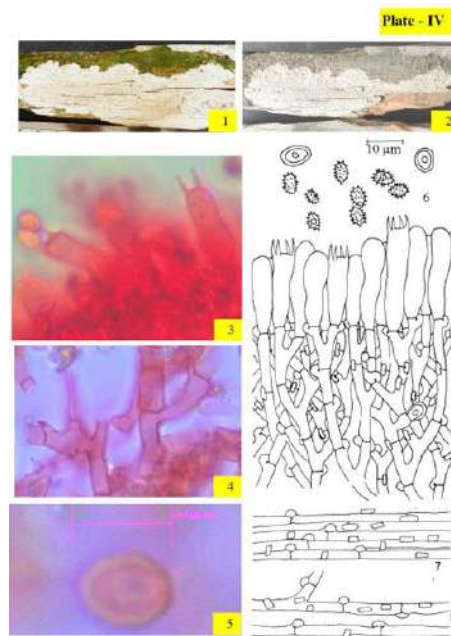
Plate–IV

Sporophore annual, resupinate, closely adnate, effused, up to $\leq 280 \mu\text{m}$ thick in section; hymenial surface grandinioid both in fresh and dry states; orange white both in fresh and dry states; margins, fibrillose, paler concolorous when determinate. Generative $\leq 3.3 \mu\text{m}$ wide, subhyaline, septate, clamped, thin-walled, smooth; horizontal, less branched in the subicular zone; vertical, richly branched in the subhymenial zone. Hyphal strands usually unbranched, $\leq 14 \mu\text{m}$ wide. Individual hyphae $\leq 3.3 \mu\text{m}$ wide, septate, clamped, encrusted. Chlamydospores $7.2\text{--}8.8 \times 5.6\text{--}6 \mu\text{m}$, thick-walled, guttulate. Basidia clavate to subclavate, usually

constricted, $21-29 \times 5.6-6.4 \mu\text{m}$; sterigma $\leq 4 \mu\text{m}$ long. Basidiospores $4-5.6 \times 2.4-3.3 \mu\text{m}$ ellipsoid, thin-walled, smooth, acyanophilous, inamyloid.

Collections Examined: India: Himachal Pradesh, Chamba, Churah, Bhandal, on stump of *Pinus wallichina*, Poonam 7866 (PUN), September 15, 2014; Bhandal, on stump of *Pinus wallichina*, Poonam 10427 (PUN), September 15, 2014; Kohladi, on decaying bark of *Cedrus deodara*, Poonam10428 (PUN), July 15, 2015; Hardaspura, on sticks of *Robenia pseudoacacia*, Poonam 10429 (PUN), August 19, 2015.

Remarks: This species is being described for the first time from tehsil Chamba. It has earlier been described from India by Rattan (1977) from district Shimla (H.P.). Later, Singh (2007) described it from districts Chamba (H.P.) and (Punjab), Sharma (2012) reported it from districts Uttarakhand and Shimla (H.P.). Jaspreet Kaur (2012) reported it from districts Chamba and Mandi (H.P.), a mention of which has also been made by Prasher and Ashok (2013). Ranadive (2013) listed it from various localities of India and Dhingra et al. (2014) from H.P. Samita (2014) reported it from Uttarakhand. Devi (2019) reported it from district Kangra (H.P.).



Figs. 1– 8. *Trechispora alnicola* :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-5. Photomicrographs (3. A portion of V.S. of sporophore showing basidiospores and basidia, 4. Generative hyphae, 5. Chlamydo-spore); 6-8. Line diagrams [6. Basidiospores; 7. Reconstruction showing a portion of hymenium and subhymenium, 8. Generative hyphae]

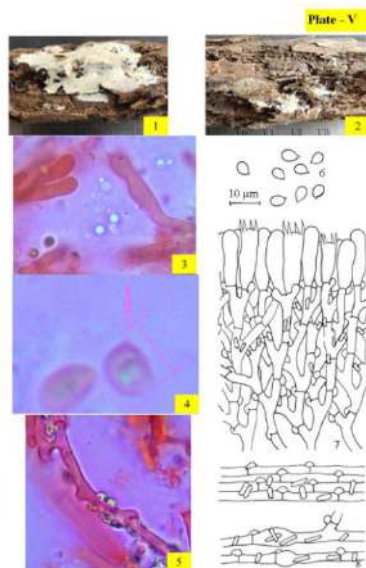
2. *Trechispora cohaerens* (Schwein.) Jülich & Stalpers, Verhandelingen Koninklijke Nederlandse Akademie van Wetenschappen Afdeling

**Natuurkunde 74: 257 (1980). - *Sporotrichum cohaerens* Schwein.,
Transactions of the American Philosophical Society 4 (2): 272 (1832).
Plate-V**

Sporophore annual, resupinate, closely adnate, effused, up to ≤ 280 μm thick in section; hymenial surface aculeate both in fresh and dry states; orange white to pale orange both in fresh and dry states; margins, fibrillose, whitish to paler concolorous when determinate. Hyphal strands present in the subiculum and margins. Generative hyphae ≤ 3.2 μm wide, subhyaline, closely septate, clamped, generally with ampullate septa, thin-walled; horizontal, less branched, with crystalline material in the subicular zone; vertical, richly branched, smooth in the subhymenial zone. Hyphal strands usually unbranched, ≤ 11 μm wide. Individual hyphae ≤ 3.3 μm wide, septate, clamped, encrusted. Basidia subclavate to clavate, $14\text{--}20 \times 4.4\text{--}5.5$ μm ; sterigma ≤ 4 μm long. Basidiospores $3.2\text{--}5 \times 2.4\text{--}4$ μm broadly ellipsoid, thin-walled, smooth, acyanophilous, inamyloid.

Collection Examined: India: Himachal Pradesh, Chamba, Churah, Bhandal, on log of *Pinus wallichiana*, 10426 Poonam (PUN), August 17, 2014.

Remarks: This species is being described for the first time from tehsil Churah in the study area. Singh (2007) reported it from District Chamba and Dhingra et al. (2014) listed it from districts Chamba and Kullu (Himachal Pradesh).



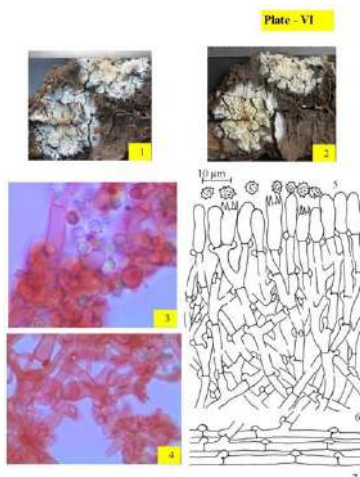
Figs. 1– 8. *Trechispora cohaerens* :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-5. Photomicrographs (3. Basidium, 4. Basidiospores, 5. Generative hyphae); 6-8. Line diagrams [6. Basidiospores; 7. Reconstruction showing a portion of hymenium and subhymenium; 8. Generative hyphae]

3. *Trechispora farinea* (Pers.) Liberta, Taxon 15: 318 (1966). – *Hydnum farineum* Pers., Synopsis methodica fungorum: 562 (1801). Plate–VI

Sporophore annual, resupinate, closely adnate, effused, up to ≤ 240 μm thick in section; hymenial surface odontoid both in fresh and dry states; pale yellow to pale orange to grayish orange both in fresh and dry states; margins, fibrillose, paler concolorous when determinate. Hyphal strands present in the subiculum and margins. Generative hyphae ≤ 3.3 μm wide, subhyaline, septate, clamped, thin-walled, smooth; horizontal, less branched in the subicular zone; vertical, richly branched, short-celled in the subhymenial zone. Basidia subclavate to subcylindrical, $9.5\text{--}17 \times 3.8\text{--}4.9$ μm ; sterigma ≤ 4.4 μm long. Basidiospores $4\text{--}5.2 \times 3.3\text{--}4.9$ globose to subglobose, thin-walled, verrucose, smooth, acyanophilous, inamyloid.

Collections Examined: India: Himachal Pradesh, Chamba, Khajjiar on stump of *Cedrus deodara* Poonam 7865 (PUN), October 12, 2012; Khajjiar on stump of *Cedrus deodara* Poonam 10430 (PUN), October 12, 2012; Churah, Bhandal, on stump of *Pinus wallichina*, Poonam 10431 (PUN), September 14, 2014; Bharmour, Manimahesh, Tosh ka got, on log of *Pinus roxburghii*, Poonam 10432 (PUN), September 04, 2016.

Remarks: This species is being described for the first time from tehsils Churah and Bharmour in the study area. It was first reported from India by Rattan (1977) from districts Mandi, Kullu, Chamba, Shimla and Solan (H.P.) and Uttarakhand. Singh (2007) described it from district Chamba (H.P.), followed by Kaur (2012) from district Solan (H.P.). Sharma (2012) reported it from Uttarakhand. Ranadive (2013) and Dhingra et al. (2014) listed it from different localities of India. Samita (2014) reported it from Uttarakhand. Kaur (2017) reported it from Punjab.



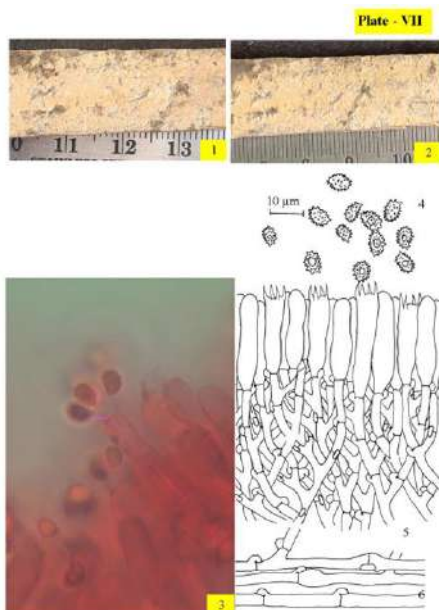
Figs. 1– 7. *Trechispora farinea*: 1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-4. Photomicrographs (3. Basidiospores, 4. Generative hyphae); 5-7. Line diagrams [5. Basidiospores; 6. Reconstruction showing a portion of hymenium and subhymenium; 7. Generative hyphae]

4. *Trechispora fastidiosa* (Pers.) Liberta, Taxon 15: 318 (1966). - *Corticium foetidum* Pers., Annalen der Botanik (Usteri) 15: 15 (1795). Plate-VII

Sporophore annual, resupinate, adnate, effused, up to ≤ 200 μm thick in section; hymenial surface hypochnoid to smooth both in fresh and dry states; light orange to grayish orange both in fresh and dry states; margin byssoid, paler concolorous when determinate. Generative hyphae subhyaline, septate, clamped, thin-walled, smooth, rarely with ampulaceous septa; horizontal, ≤ 3.5 μm wide, less branched in the subicular zone; vertical, ≤ 3 μm wide branched, richly branched in the subhymenial zone. Basidia subclavate to clavate, $20\text{--}29 \times 5.8\text{--}6.6$ μm ; sterigma ≤ 4.4 μm long. Basidiospores $4.8\text{--}6.4 \times 3.3\text{--}4.8$ μm ellipsoid to broadly ellipsoid, thin-walled, verrucose, smooth, acyanophilous, inamyloid.

Collection Examined: India: Himachal Pradesh, Chamba, Khajjiar on log of *Cedrus deodara* Poonam 10424 (PUN), October 12, 2012.

Remarks: *T. fastidiosa* is being redescribed from tehsil Dalhousie in the study area. Dhingra (1983) was the first to report this species from Meghalaya (Eastern Himalaya), followed by Singh from district Chamba. Kaur (2012) reported it from district Mandi (H.P.).



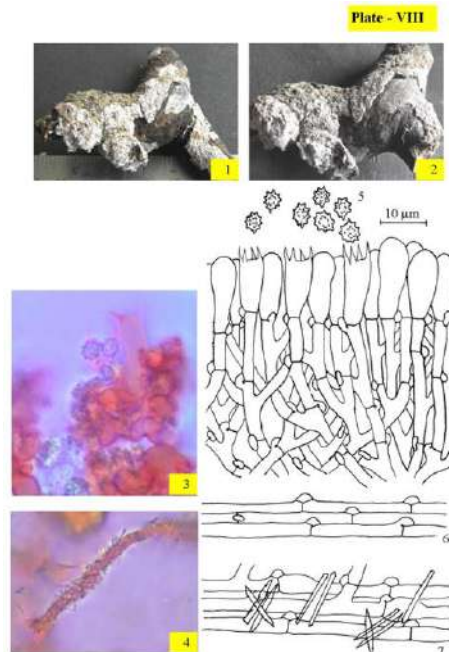
Figs. 1– 6. *Trechispora fastidiosa* :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3. Photomicrograph of V.S. of sporophore showing Basidiospores and basidium; 4-6. Line diagrams [4. Basidiospores; 5. Reconstruction showing a portion of hymenium and subhymenium; 6. Generative hyphae]

5. *Trechispora microspora* (P. Karst.) Liberta, Taxon 15: 319 (1966). - *Grandinia microspora* P. Karst., Bidrag till Kännedom av Finlands Natur och Folk 48: 365 (1889). Plate-VIII

Sporophore annual, resupinate, adnate, effused, thin, easily separable from the substrate, up to $\leq 160 \mu\text{m}$ thick in section; hymenial surface smooth to graninoid both in fresh and dry states; yellowish white to orange white to pale orange both in fresh and dry states; margins fibrillose, paler concolorous when determinate. Hyphal strands present in the subiculum and margins. Generative hyphae $\leq 3 \mu\text{m}$ wide, subhyaline, septate, clamped, thin-walled; horizontal, less branched, encrusted with aceroses crystals in the subicular zone; vertical, richly branched, smooth in the subhymenial zone. Hyphal strands usually unbranched, $\leq 10 \mu\text{m}$ wide. Individual hyphae $\leq 2.8 \mu\text{m}$ wide, septate, clamped. Basidia subclavate to subcylindrical, $11-15 \times 4.9-5.5 \mu\text{m}$, sterigma $\leq 3.8 \mu\text{m}$ long. Basidia subclavate to clavate, $20-29 \times 5.8-6.6 \mu\text{m}$; sterigma $\leq 4.4 \mu\text{m}$ long. Basidiospores $3.3-4.6 \times 3-3.6 \mu\text{m}$ broadly ellipsoid to subglobose, thin-walled, verrucose, smooth, acyanophilous, inamyloid.

Collection Examined: India: Himachal Pradesh, Chamba, Hardaspura, on decaying sticks of *Ficus religiosa* Poonam 10425 (PUN), April 26, 2015.

Remarks: *T. microspora* is being described for the first time from tehsil Chamba. Earlier it was reported by Dhingra and Singla (1993) from District Chamba (H.P.), Dhingra et al. (2014) also listed it. Lalji (2003) reported it from Uttarakhand, Kaur (2017) reported it from Punjab.



Figs. 1– 7. *Trechispora microspora* :1-2. Sporophore showing hymenial surface (1. Fresh, 2. Dry); 3-4. Photomicrographs (3. Basidiospores, 4. Encrusted generative hyphae); 5-7. Line diagrams [5. Basidiospores; 6. Reconstruction showing a portion of hymenium and subhymenium, 7. Generative hyphae]

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Clean Development Mechanism and Climate Change Policy in India

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Introduction

Climate change can be defined as the change in statistical distribution of weather patterns or average weather conditions, when the change lasts for 30 years or more as per the World Meteorological Organization. The climate of the earth has never been steady, in fact, in the last 6,50,000 years, there have been seven cycles of glacial retreat and advance, with a sudden end of the last ice age era 7,000 years ago, giving rise to a new era of modern climate change.

Various factors, either internal or external forcing mechanisms, can be simultaneously responsible for climate change. These forcing mechanisms were naturally influenced up to 1950s but after the start and advancement of industrial revolution, the average world temperature increased by 0.8 to 1.5 °C (<https://www.wur.nl/en/show/Causes-of-climate-change.htm>).

It is very likely that most of the global warming and temperature rise can be attributed to an observed increase in GHGs (greenhouse gases), the most important ones being CO₂ (carbon dioxide), CH₄ (methane), N₂O (nitrous oxide), O₃ (ozone), water vapour and fluorinated gases. CO₂ is the primary GHG (greenhouse gas) recently contributing to climate change.

These anthropogenic activities currently release more than 30 billion tons of CO₂ in the atmosphere per year (IPCC, 2013). CH₄ is produced naturally through wetlands by anaerobic biodegradation, and anthropogenic ally through agricultural activities, transport through vehicular emissions and fossil fuel extraction.

Global sea water levels have also increased from added water due to melting land ice and expanding sea water, by ~8 inches since the year 1880 and are projected to yet increase by 19 inches feet by the year 2050 (IPCC 2013). This increase in sea

water levels with storm surges and high tides can increase flooding in coastal cities (USGCRP, 2017). Temperatures are on the rise in the Polar Regions, especially in the Arctic, causing faster melting of the vast majority of the world's glaciers than new snow and ice can replenish them. Scientists have predicted that the rate of melting will accelerate, with serious implications for future sea level rise.

India is among the countries most vulnerable to climate change. It has one of the highest densities of economic activity in the world, and very large numbers of poor people who rely on the natural resource base for their livelihoods, with a high dependence on rainfall. By 2020, pressure on India's water, air, soil, and forests is expected to become the highest in the world. One of the most significant ways that climate change will impact the lives of people in India will be through its water resources.

Research Methodology

The details of climate change mechanisms, policies and incentives in India and abroad for climate change and CDMs (Clean Development Mechanism) cannot be sufficiently addressed by any single form of method. These can be more precisely studied by comparing and using qualitative and quantitative data together rather than singularly.

Descriptive method of research was used in this study to gather information about the current extent of climate change, the existing policies for climate change in India and abroad, and the CDMs and their success and limitations in present conditions. Descriptions were used in the study rather than interpretations and opinions, except for chapters 6 and 7, which required a pragmatic approach to problem solving. Data were compiled from books, literature reviews, case studies, articles, legislations, and research works of other authors, international and national reports and public databases, results of forecasting models and others and then elucidated to form the crux of the issue to be addressed.

Climate Change Policies

Scientific concerns about global warming have grown considerably since the 1980s, especially in the year 1988, when North America suffered extensive damage from an intense heat wave and subsequent draught. These concerns gave rise to establishment of IPCC by the WMO (World Meteorological Organization) and UNEP (United Nations Environment Programme) for investigation of reports on scientific evidence and possible international responses to climate change. The first assessment report (in 1990) regarding the development of climate change policies was considered while drafting the UNFCCC (United Nations Framework Convention on Climate Change) in 1991. A total of 166 nations became signatories for this framework at the Earth Summit in Rio de Janeiro in 1992 and it came into force in 1994. Specific national/ international targets to reduce GHG emissions were not included in the UNFCCC but it enlisted the key points and principles,

which have been foundational in subsequent international climate change debates and processes.

Most prominent of the principles were

- Stabilization of the climate to prevent dangerous anthropogenic influence on climate system, within a time frame allowing natural systems to adapt without major damage to food systems and economic development (Smith et al, 2009).
- Need for nations to monitor and limit their GHG emissions, considering the nations' responsibilities and capacities. Particular concerns would be for developing countries with limited resources and those most vulnerable to damaging climate change impacts, such as small island states (Smith et al, 2009).
- Stressing on the importance of precautionary measures for better response to severe climatic threats (Klein et al, 2005).

Adaptation Strategies for Climate Change

Adaptation to climate change is another aspect of climate change policies, which anticipates the effects of climate change and takes appropriate action for prevention or minimization of the damage caused. It is based on the principle that early action on climate change saves on costs occurred on damage. These strategies for adaptation are essential at every national and international level of administration. It involves multiple levels of decision making and causes effects on many economic sectors. Adaptation strategies are required to be integrated in different policy areas: coastal zone management, agriculture and rural development, regional development, disaster risk reduction, health services, spatial planning and ecosystems and water

Clean Development Mechanisms

CDMs The CDM as defined in Article 12 of the Kyoto Protocol allows a signatory nation with an emission-reduction or emission-limitation commitment under Kyoto Protocol to implement an emission-reduction project in developing countries. These projects can earn saleable CER (Certified Emission Reduction) credits, each equivalent to one ton of CO₂, which can be counted towards meeting Kyoto targets. This mechanism is the first global environmental investment and credit scheme of its kind, providing CERs as the standardized emissions offset instrument for measurement the-kyoto-protocol/the-clean-development-mechanism). This mechanism encourages emission reductions with sustainable development while giving developed industrialized nations flexibility in the way they meet their emission reduction targets.

Applications of CDMs

CDMs are the first and the largest carbon offset instrument in the world and to date, the only market based environmental commodity which attracted several billions of euros of private capital on an annual basis. Being a novel climate change mitigation

instrument, the CDM followed trial and error learning pattern thus undergoing reforms since its origin. Although the future of this mechanism remains uncertain, the lessons from past CDM experiences are useful for CDM reforms and also for new market instruments (Shishlov et al, 2012).

The economic efficiency of the CDM projects is a widely discussed topic. The CDM proved to be a useful tool for the identification of new GHG abatement opportunities in spite of being mostly concentrated on the supply side with over 93% of the issued credits coming from 5 countries. However, it failed to scale such projects up across the economies. Majority of the demand for carbon offsets came from the European Union ETS, where CDM helped companies save millions of capitals by reducing emissions at the cheapest projects. With the quantitative restrictions in place, the demand for CDM offsets from projects registered after 2012 have reduced to a few public buyers reduced by the size of supply (CDM watch, 2012).

Conclusion

India has earned a huge amount of CERs and foreign currency by selling CERs in the world market. Currently the main flourishing sector for CDM is renewable energy. The limitation of CDM projects in India is the continuous fall of CER prices worldwide, and non-transparency in certification of CERs. The commissioning of CDM projects in India need to be improved with respect to involvement of the general people in project activities. Projects should also be studied to reduce transaction cost, registration cost, long time consumption of CDM cycle, regional disparity in project distribution and high percentage of rejection of the projects by the Executive Board at international level.

The public sector units should be given knowledge of CDM projects and the opportunities they offer and they should be encouraged to consider CDM business plans. Small scale industries, which represent a very high portion of the industrial units in India, should also be involved in these projects. The wide gap between the management and the working levels in industries should be reduced by involving majority of the workers in the projects.

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Bio-Diversity Conservation in a Changing World

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Environmental Biodiversity: Definitions, Threats, Importance, and Conservation

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Abstract

Biodiversity, defined by the 1992 Convention on Biological Diversity, includes genetic, species, and ecosystem variability essential for life. Human-induced losses via habitat disruption and invasives threaten this wealth, yet it underpins water protection, medicine, and climate stability. This paper examines levels, threats, benefits, and proactive conservation needs.

Keyword: Biodiversity, Protection of water resources, Types of Biodiversity

Introduction

According to the 1992 Convention on Biological Diversity, biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and aquatic ecosystems and their ecological complexes. This encompasses diversity within species, between species, and of ecosystems. Biological diversity refers to the variety of life forms—plants, animals, microorganisms—the genes they contain, and the ecosystems they form. This living wealth results from hundreds of millions of years of evolution, where the pool dynamically increases with new genetic variations, species, or ecosystems, and decreases via extinctions. Humans have long observed biodiversity, but the term entered public discourse around 1988. It spans molecular to biospheric levels: genetic, species, and ecosystem diversity.

Data and Methodology

This review paper employs a qualitative, desk-based approach:

- Literature synthesis from textbooks and studies on biodiversity definitions, threats (e.g., habitat loss data), and benefits.

- Secondary data analysis: Species estimates (e.g., India's biota), case studies (Dodo, Parthenium), and global stats (rainforest loss). No primary fieldwork; relies on cited sources up to 2025 updates.
- Logical structuring: Conceptual framework → Threats → Importance → Policy shift.

Levels of Biodiversity

a. Genetic Diversity

This is the variety of genetic information in plants, animals, and microorganisms within and between populations. Estimates suggest ~10 billion genes worldwide, with conserved core genes showing low variation and specialized ones higher.

b. Species Diversity

The variety of species, measured by richness (number in an area), abundance (relative numbers), and phylogeny. ~2.2 million species described as of 2025 (56% insects, 14% plants; vertebrates ~3%; oceans ~15%). India boasts ~50,000 plants, 81,000 animals (20,000 flowering plants, 67,000 insects, etc.).

c. Ecosystem Diversity

Variations in landforms supporting unique vegetation; challenging to measure due to fluid community boundaries. It involves biological communities, ecosystems, and interactions across niches.

Problem of Biodiversity Loss

Extinction of plants and animals has been a natural phenomenon during evolution. Extinction generally refers to the death of a group or species. However other kinds of extinction also occur like local extinction and ecological extinctions. All these extinctions have one key aspect in common that they all cause biodiversity loss.

The loss of biodiversity has become a serious environmental problem. Species are becoming extinct at a faster rate and mostly it is due to human activity. Some of the causes of extinction may be enumerated as follows:

a. Habitat Disruption

It refers to disturbance of the physical environment in which a species lives. Such disturbances can range from minor to drastic. Minor disturbances such as mild chemical changes from air pollution tend to affect only the most susceptible species. In contrast, extreme physical changes in habitat can eliminate many species from the area. Deforestation of tropical rainforest by burning and other agricultural practices is one of the most publicized examples of massive habitat disruption. It may be mentioned here that tropics contain more species than other areas. According to an estimate, rain-forests contain over 50% of the world's species though they cover only 7% of the Earth. As of 1995 about one-half of the rainforest

had been deforested, which to some experts mean perhaps a 10% rainforest species loss so far.

b. Introduction of Exotic (non-native) Species

It can disrupt entire ecosystem and adversely affect population of native plants or animals. These invader species can have devastating effects on native species by predation, infection, competition or mating with them. *Parthenium* (gajer grass) is one common example, which invaded in our country from America with PL 480 wheat-aid and now proliferating in every corner of the country creating serious environmental problem. Exotic species are especially important as a cause of extinction on islands. Because of their isolation native island species are often poorly adapted to cope with new species. An example are ground birds that evolved on many islands such as New Zealand and Hawaii in the absence of large predators. The introduction of domestic cats and dogs alone has driven dozens of island ground bird species to extinction or near extinction.

c. Over-Hunting

Over-hunting of species decline caused by excessive shooting, trapping or poisoning of organisms. Usually this is done for sport or economic reason. Classical example as that of tiger extinction in central India.

d. Secondary Extinction

Secondary extinctions occur when the extinction of one group causes the extinction of another. Often this involves the loss of a food species. The well-known extinction of the Dodo bird of Maritus, for instance has caused the *Calveria* tree to become unable to reproduce. When the dodo ate the seeds of the tree, it digested the outer seed covering, allowing the seed to grow. But the extinction of dodo became crucial to the reproduction of the *Calveria* tree.

Importance of Biological Diversity

Today, as ever human beings are dependent for their sustenance, health, well-being and enjoyment of life on fundamental biological systems and processes. Human derives all of its food and many medicines and industrial products from the wild and domesticated components of biological diversity. Biotic resources also serve recreation and tourism and underpin the ecosystems which provide us with many services.

While the benefits of such resources are considerable, the value of biological diversity is not restricted to these. The enormous diversity of life in itself is of crucial value, probably giving greater resilience to ecosystems and organisms. Biodiversity also has important social and cultural values. Generally, benefits arising from the conservation of components of biological diversity can be considered as follows.

In Protection of Water Resources: Natural vegetation cover in water catchments helps to maintain hydrological cycles, regulating and stabilising water runoff and acting as a buffer against extreme events such as flood and drought. Vegetation removal results in siltation of catchment waterways, loss of water yield and quality and degradation of aquatic habitat, among other things. Vegetation also helps to regulate underground water tables, preventing dry land salinity which affects vast areas of agricultural lands at great cost to the community. Wetlands and forests act as water purifying systems, while mangroves trap silt, reducing impacts on marine ecosystems.

In Soil formation and Protection: Biological diversity helps in the formation and maintenance of soil structure and the retention of moisture and nutrient levels. The loss of biological diversity through clearing of vegetation has contributed to the salinisation of soils, leaching of nutrients, laterisation of minerals and accelerated erosion of topsoil, reducing the land's productivity. Trees on the other hand, lower the water table and remove deposited salt from the upper soil horizons. Soil protection by maintenance of biological diversity can preserve the productive capacity of the soil, prevent landslides, safeguard coastlines and riverbanks and prevent the degradation of coral reefs and riverine and coastal fisheries by siltation.

In Pollution Control: Ecosystems and ecological processes play an important role in the breakdown and absorption of many pollutants created by humans and their activities. These include wastes such as sewage, garbage and oil spills. Components of ecosystems from bacteria to higher life forms are involved in these breakdown and assimilative processes. Excessive quantities of any pollutant however can be detrimental to the integrity of ecosystems and their biota. Some ecosystems especially wetlands, have qualities that are particularly well suited to breaking down and absorbing pollutants. Natural and artificial wetlands are being used to filter effluents to remove nutrients, heavy metals and suspended solids, reduce the biochemical oxygen demand and destroy potentially harmful microorganisms.

In Climate Stability: Vegetation influences climate at the macro and micro levels. Growing evidence suggests that undisturbed forest helps to maintain the rainfall in its immediate vicinity by recycling water vapor at a steady rate back into the atmosphere and through the canopy's effect in promoting atmospheric turbulence. At smaller scales vegetation has a moderating influence on local climates and may create quite specific micro-climates. Some organisms are dependent on such micro-climates for their existence.

In Maintenance of Ecosystems: Ecosystem relationships resemble a web of connections from one living thing to many other living and non-living things. They not only allow survival but also maintain a balance between living things and the resources (such as food and shelter) they need to survive. Vegetation is integral to

the maintenance of water and humidity levels and is essential for the maintenance of the oxygen/carbon dioxide balance of the atmosphere.

As Food: Human existence is heavily dependent on primary producers, mainly plants. Five thousand plant species have been used as food by humans, but less than twenty now feed the majority of the world's population and just three or four carbohydrate crops are staples for a vast majority. One of the important benefits of conservation of biodiversity is the wild plant gene pool which is available to augment the narrow genetic base of these established food crops, providing disease resistance, improved productivity and different environmental tolerances for enhancing agricultural productivity.

As Medicinal Resources: People have long used biological resources for medicinal purposes. Everywhere aboriginal societies made use of many native plants as medicines. A few aboriginal medicines have been widely used in Asian medicine such as the ubiquitous eucalyptus oil for relief of respiratory tract infections, but many more are now being investigated.

Wild plant, animal and microorganism resources are also of great importance in the search for new medically active compounds and the potential of other biota to contribute to modern medicine has scarcely begun to be realised. Many of the drugs presently used are derived from plants, many medicines, in particular antibiotics are derived from microorganisms, and new chemical structures are being discovered all the time. The native pepper (*Piper novae-hollandiae*) and the black bean (*Castanospermum australe*) both offer potential in the treatment of cancer. Studies of various chemicals produced by animals have led to discoveries of medicinally useful substances.

Conclusion

Biodiversity conservation shifts from reactive protection to proactive sustainability, safeguarding wild/domesticated genetics for ecological balance and human needs. . The conservation of biological diversity seeks to maintain the life-support system provided by nature in all its variety and the living resources essential for ecologically sustainable development.

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