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COMPARATIVE BIODIVERSITY OF VERTEBRATES IN MAHARASHTRA ECOSYSTEMS

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ABSTRACT

This study, Comparative Biodiversity of Vertebrates in Maharashtra Ecosystems, examines vertebrate diversity, distribution, and ecological roles across Maharashtra's varied landscapes, including forests, wetlands, rivers, reservoirs, grasslands, coastal zones, and arid regions. Maharashtra is recognised as one of India's ecological hotspots, supporting a wide range of mammals, birds, reptiles, amphibians, and fishes. By comparing vertebrate biodiversity across these ecosystems, the study identifies environmental and human factors that influence species richness and ecological balance. Using scientific literature, biodiversity surveys, government reports, and conservation databases, we mapped vertebrate diversity and the challenges it faces. Our findings indicate that forests and wetlands, due to their complex habitats and abundant water, support the highest vertebrate diversity.

In contrast, Maharashtra's semi-arid and urban areas support fewer species, with habitat loss and ongoing human activity reducing biodiversity. The study identifies key threats, including deforestation, pollution, urban expansion, climate change, roadkill, agricultural growth, mining, and increasing human-wildlife conflict. Freshwater and coastal habitats are particularly vulnerable to pollution and unregulated development, while forests face growing fragmentation. The research emphasises the importance of protected areas, wildlife corridors, wetland conservation, habitat restoration, and continuous ecological monitoring. Conservation strategies should be tailored to each ecosystem's specific needs. The study ultimately calls for an integrated, ecosystem-based approach that combines scientific research, community involvement, effective policy, and sustainable management to protect Maharashtra's vertebrate diversity.

KEYWORDS: *Biodiversity, Ecological hotspots, Habitat, vertebrates, reports*

INTRODUCTION

Biodiversity is the variety of life on Earth, from genes and species to ecosystems and biomes. It is not just an aesthetic or philosophical issue but a crucial foundation for the biosphere's health. The permanent loss of species, populations, and habitats is a major ecological crisis of the twenty-first century. This loss threatens ecosystem services that human civilisation relies on, such as food security, clean water, climate regulation, and natural defences against disease and invasive species. The current rate of biodiversity loss, often called the sixth mass extinction, is unprecedented since complex life began. Its long-term effects on ecosystems, evolution, and human well-being remain uncertain.

Of the many groups ecologists, conservationists, and policy-makers track to measure ecosystem health, vertebrates are especially important. They are generally larger, play many roles in ecosystems, are key parts of food webs, and are better studied than invertebrates, fungi, or most plants. Because of their ecological importance and the information available, vertebrates help us understand broader ecological processes, assess ecosystem health, and plan conservation efforts. Their appeal also helps gain public support for conservation, which is especially important in a country like India with many challenges and priorities.

India is one of the world's seventeen mega-diverse countries, with about 7–8% of all known species, though it covers less than 2.4% of the world's land. [1] This rich biodiversity stems from India's unique geological history, its location at the crossroads of several biogeographic regions, its varied terrain and monsoon-shaped climate, and millions of years of evolution. Within India, Maharashtra holds a special ecological place. Covering about 307,713 square kilometres, Maharashtra includes two very different and important landscapes: the Western Ghats, a globally recognised biodiversity hotspot, and the Deccan Plateau, a large semi-arid region with unique species that have drawn more scientific interest recently. [2] Because these different landscapes meet in Maharashtra, the state has a wide variety of habitats, microclimates, soils, and species. Maharashtra's vertebrates show this diversity, with hundreds of species of fish, amphibians, reptiles, birds, and mammals. Many are globally threatened or found only in this region. [3] The Western Ghats forests host species found nowhere else, while the Deccan grasslands support a different, increasingly threatened group of open-country vertebrates. Between these areas are

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transition zones, river corridors, coastal wetlands, cities, and farmlands, each with unique vertebrate communities and conservation issues.

Although Maharashtra's vertebrate diversity is important, few studies compare biodiversity patterns, ecological factors, and conservation status across different vertebrate groups and ecosystems in the state. This work aims to fill that gap by offering a broad assessment of vertebrate biodiversity in Maharashtra's main ecosystems. It examines the ecological and evolutionary processes shaping these communities, reviews conservation threats and their effects on species and habitats, and suggests research and policy priorities for protecting this unique regional wildlife.[4]

Geological and Physiographic Overview

Maharashtra's geography is defined by two main geological formations: the Deccan Trap basalts and the Western Ghats. The Deccan Trap, created by volcanic activity 66 million years ago, shapes the state's interior with flat-topped mesas, incised valleys, and varied soils that influence vegetation and wildlife [5]

The Western Ghats, an erosional scarp along the western edge, produce a sharp climatic gradient that affects monsoon patterns and biodiversity. [6]

Major rivers such as the Godavari, Krishna, and several smaller westward-draining rivers contribute to ecological diversity by supporting a range of freshwater and coastal ecosystems [7]

Biogeographic Affinities and Historical Context

Maharashtra's position at the intersection of major Indian biogeographic zones supports a diverse vertebrate fauna with deep historical origins. The Western Ghats' forests retain Gondwanan elements, especially among amphibians and fish, dating to the Indian subcontinent's drift across the Tethys Sea 130 to 50 million years ago[8]

India's collision with Asia enabled further biotic exchanges, introducing Oriental species. [9] The Deccan Plateau shares affinities with arid regions, reflecting historical links within South Asia. [10] Contact zones between Western Ghats and Deccan fauna, particularly in Maharashtra's eastern foothills, are important areas for faunal mixing and speciation and warrant further scientific study. [11]

Principal Ecosystems of Maharashtra

Tropical Wet Evergreen and Semi-Evergreen Forests

Moist Deciduous Forests

Moist deciduous forests form a transitional zone between wet evergreen and dry deciduous forests and are mainly found on the mid-elevation western slopes and in the Satpuda ranges of northern Maharashtra. Although structurally simpler than wet evergreen forests, they support high vertebrate diversity. Key protected areas include Sahyadri Tiger Reserve, Chandoli National Park, and parts of Pench and Melghat Tiger Reserves. The Satpuda range's moist deciduous forests, especially Melghat Tiger Reserve, provide important habitats for species such as the Bengal Tiger, Leopard, Gaur, Sambar, Wild Dog, and over 300 bird species. [12]

Dry Deciduous Forests

Dry deciduous forests in central and eastern Maharashtra, including the Tadoba-Andhari Tiger Reserve, are known for dense tiger populations and unique fauna such as Chital and Wild Boar. [13]

The Deccan Plateau's grasslands, now severely reduced by agriculture, support species like the Great Indian Bustard and Indian Wolf, with over 90% habitat loss. [14]

Maharashtra's wetlands and rivers, including major reservoirs and mangroves, sustain rich biodiversity and provide important habitats for migratory waterbirds, such as large congregations of Lesser Flamingos, as well as vital fish nurseries. [12]

Vertebrate Groups of Maharashtra: Taxonomic Overview

Maharashtra's fauna includes over 200 freshwater fish species, many of which are endemic. The state's biodiversity, especially in the Western Ghats, faces major threats such as overfishing, habitat alteration, and diseases affecting amphibians, reptiles, birds, and mammals.[11] Maharashtra supports 80–100 amphibian species, over 100 snake species, and more than 550 bird species, including several that are critically endangered. Conservation efforts prioritize iconic species like the Bengal Tiger and Indian Leopard. The protected area network includes six National Parks, 47 Wildlife Sanctuaries, four Tiger Reserves, and one Biosphere Reserve, covering 5.6% of the state. The Wildlife (Protection) Act of 1972 and related laws aim to protect these species, while the Forest Rights Act recognizes the rights of forest-dwelling communities, resulting in complex governance dynamics for conservation management.[15]

MATERIALS AND METHODS

Objectives of the Present Study

This study aims to comparatively analyse vertebrate biodiversity and conservation status across Maharashtra's major ecosystems, including the Western Ghats, Vidarbha, and the Konkan Coast, to identify ecological patterns, assess threats, and propose effective, region-specific conservation strategies.

1. To assess and compare vertebrate biodiversity across major ecosystems of Maharashtra, including the Western Ghats, Vidarbha, and the Konkan Coast.
2. To analyse the distribution patterns and ecological adaptations of vertebrate species in different habitat types.
3. To evaluate the impact of anthropogenic activities on vertebrate diversity and ecosystem stability.
4. To examine the effectiveness of conservation measures in protected areas such as Tadoba Andhari Tiger Reserve and Sanjay Gandhi National Park.
5. To suggest suitable conservation strategies for sustainable management of vertebrate biodiversity in Maharashtra.

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Methods

The study uses a comparative ecological approach to examine vertebrate biodiversity and conservation in Maharashtra's ecosystems: the Western Ghats, Vidarbha, and the Konkan Coast. These regions differ in climate, vegetation, habitat, and human impact, enabling a comparison of biodiversity. Using secondary sources, the research collates data from scientific journals and conservation records to evaluate patterns in vertebrate diversity and the effectiveness of conservation measures. The study focuses on key vertebrate groups, mammals, birds, and reptiles, and assesses their sensitivity to environmental changes and anthropogenic threats such as deforestation and urbanisation. By examining protected areas, the research aims to inform conservation strategies and identify at-risk ecosystems and species, thereby enhancing biodiversity management and conservation policies in Maharashtra**.**

Research Design

The study employs a comparative research design to assess vertebrate biodiversity and conservation status across Maharashtra's diverse ecosystems, including the Western Ghats, Vidarbha, and the Konkan Coast. Variations in topography, climate, and human interference shape vertebrate diversity and the needs of ecosystem management. A descriptive approach details the distribution of major vertebrate groups, while an analytical approach evaluates ecological relationships and conservation effectiveness using secondary data from scientific publications and conservation organisations. This framework supports understanding environmental threats and biodiversity patterns essential for conservation planning in Maharashtra.

The study uses secondary data to examine biodiversity across ecosystems, drawing on scholarly articles, conservation reports, and environmental databases. This approach enables comprehensive ecological analysis by integrating large-scale, time-series data, supporting cost-effective research while maintaining reliability. It emphasises ecosystem-based assessments, considering the interdependence of species and habitats rather than focusing solely on individual species. The research design combines comparative, descriptive, and analytical methods to evaluate vertebrate diversity, ecological adaptations, and conservation efforts, aiming to formulate targeted conservation strategies for regions including the Western Ghats, Vidarbha, and the Konkan Coast.

Nature of the Study

The study focuses on vertebrate biodiversity in Maharashtra, analysing ecosystems such as the Western Ghats, Vidarbha, and the Konkan Coast. It assesses ecological characteristics, conservation status, and environmental pressures on vertebrate species, highlighting biodiversity's importance to ecosystem health. The research addresses anthropogenic threats and evaluates conservation measures in protected areas such as Tadoba Andhari Tiger Reserve. Using a cross-ecosystem comparative approach, it identifies variations in biodiversity patterns and conservation challenges, aiming to develop targeted strategies for the long-term preservation of vulnerable species and ecosystems.



Figure 1 : Soil map of Maharashtra

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Study Area Profile

The study examines three key ecosystems in Maharashtra: the Western Ghats, Vidarbha, and the Konkan Coast. These areas are chosen for their ecological diversity and significant vertebrate biodiversity. Each ecosystem has a unique climate, topography, vegetation, water conditions, and human impact, allowing for a comparative analysis of biodiversity. These regions exemplify forest, coastal, and semi-arid ecosystems that host diverse vertebrate species, facilitating an assessment of biodiversity patterns, ecological adaptations, habitat conditions, and conservation challenges in Maharashtra.

Western Ghats Ecosystem

The Western Ghats ecosystem lies along Maharashtra's western edge and forms part of one of the world's recognised biodiversity hotspots.[11] The region features dense evergreen and semi-evergreen forests, high annual rainfall, mountainous terrain, and rich vegetation cover. A favourable climate and diverse habitats support exceptional vertebrate biodiversity and endemism, particularly among amphibians, reptiles, birds, and small mammals. This ecosystem includes several ecologically sensitive habitats, such as tropical forests, hill streams, and wetlands. Protected areas and forest reserves in the Western Ghats play a crucial role in conserving wildlife populations and maintaining ecological stability. However, deforestation, tourism, infrastructure development, agricultural expansion, and climate variability increasingly affect the region, threatening habitat integrity and species survival.[16,17]

Vidarbha Ecosystem

The Vidarbha ecosystem is located in eastern Maharashtra and is primarily dominated by dry deciduous forests and grassland habitats. Compared with the Western Ghats, Vidarbha has lower rainfall, greater temperature variation, and longer dry seasons. Despite these climatic conditions, the region supports rich vertebrate diversity, especially large mammals such as tigers, leopards, deer, wild boars, and other herbivores. Tadoba Andhari Tiger Reserve is one of the most important protected areas in this ecosystem and provides significant habitat for apex predators and associated wildlife. Forest cover, seasonal water availability, and habitat connectivity strongly influence Vidarbha's ecological structure. Human-wildlife conflict, mining activities, deforestation, and agricultural expansion represent major conservation challenges in this region. Nevertheless, Vidarbha remains ecologically significant because it sustains wildlife populations and maintains forest ecosystem processes.[18,19]

Konkan Coast Ecosystem

The Konkan Coast ecosystem extends along the Arabian Sea and represents Maharashtra's coastal ecological zone. This region includes mangroves, estuaries, wetlands, sandy beaches, and coastal forests that provide habitat for a diverse range of vertebrate fauna. Fish diversity is particularly high in this ecosystem because of its marine and estuarine environments, and migratory birds and amphibious species are also commonly observed. The humid coastal climate, saline influence, and moderate temperatures create specialised ecological conditions that differ considerably from inland ecosystems. Mangrove ecosystems along the Konkan Coast perform important ecological functions, including shoreline protection, support for aquatic organism breeding, and nutrient cycling. However, rapid urbanisation, industrial development, coastal tourism, pollution, and sea-level rise have intensified ecological degradation within the region. These environmental pressures threaten biodiversity conservation and ecosystem sustainability along the Maharashtra coastline.[20,21]

Sources of Data

This study primarily uses secondary data from a wide range of scientific, governmental, and institutional sources on biodiversity, ecology, wildlife conservation, and environmental management. Because the research aims to comparatively analyse vertebrate biodiversity and conservation status across multiple ecosystems in Maharashtra, secondary data provide access to extensive ecological information across different geographical regions, vertebrate groups, and conservation contexts. Secondary sources are particularly useful in biodiversity research because they provide scientifically verified, systematically documented information from previous ecological studies, wildlife surveys, and conservation assessments. The collected data has been utilised to analyse species diversity, habitat characteristics, ecological adaptations, anthropogenic threats, and conservation measures within the Western Ghats, Vidarbha, and the Konkan Coast ecosystems.

The study used secondary data from research journals, forest department publications, wildlife census reports, biodiversity databases, books, and official conservation reports. Peer-reviewed research journals are among the most important sources of ecological and biodiversity-related information. These journals provide scientific studies on vertebrate diversity, habitat ecology, species distribution, conservation status, ecosystem functioning, and environmental threats affecting biodiversity in Maharashtra and other ecological regions of India. We consulted academic databases such as Scopus and Google Scholar to access recent, relevant literature on wildlife biology, conservation ecology, and environmental management.

Forest department reports and wildlife census publications provide region-specific information regarding wildlife populations, protected areas, forest cover, habitat conditions, and conservation activities. Reports from the Maharashtra Forest Department and the Ministry of Environment, Forest and Climate Change (MoEFCC) provide valuable statistical and ecological data on biodiversity management and conservation policies. Wildlife census reports are particularly important for understanding population trends of major vertebrate species, especially large mammals such as tigers, leopards, deer, and other wildlife species inhabiting protected areas including Tadoba Andhari Tiger Reserve and Sanjay Gandhi National Park.

Government biodiversity databases and conservation organisations also serve as major sources of information for the study. Databases and institutional records maintained by organisations such as the International Union for Conservation of

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Nature (IUCN), World Wide Fund for Nature (WWF), and Zoological Survey of India (ZSI) provide information regarding species classification, conservation status, endangered species categories, ecological threats, and biodiversity assessments. These sources are widely recognised for their scientific reliability and contribute significantly to biodiversity monitoring and conservation planning.

The study also consulted published books, ecological reports, and conservation documents to build a theoretical understanding and gather supporting information on ecosystem diversity, ecological principles, vertebrate adaptations, and conservation strategies. These materials help establish a broader conceptual framework for interpreting biodiversity patterns and conservation challenges across Maharashtra's ecosystems.

Table 1: Data resources

Source Type	Examples
Government Reports	Maharashtra Forest Department, MoEFCC
Research Articles	Scopus, Google Scholar
Biodiversity Databases	IUCN, WWF, ZSI
Conservation Reports	WWF-India, NBWL
Published Books	Wildlife ecology and biodiversity books
Census Reports	Tiger census and wildlife survey reports

Variables of the Study

This study examines vertebrate biodiversity and conservation status across selected ecosystems in Maharashtra by analysing ecological and environmental variables. We group variables into biodiversity, environmental, and anthropogenic categories to enable systematic assessment and comparison. These variables clarify patterns in species diversity, habitat conditions, ecological adaptations, and human impacts on ecosystem stability. We selected them for their ecological relevance and influence on vertebrate distribution and conservation in the Western Ghats, Vidarbha, and Konkan Coast.

Biodiversity Variables

Biodiversity variables assess the diversity, composition, and distribution of vertebrate species within the selected ecosystems. One primary biodiversity variable considered in the study is species richness, the total number of vertebrate species present in a particular ecosystem or habitat. Species richness is an important ecological indicator because it reflects an area's overall biological diversity and ecological complexity. Ecosystems with higher species richness are generally considered ecologically stable and biologically productive.

Another important biodiversity variable included in the study is species abundance. Species abundance refers to the relative number of individuals belonging to different vertebrate species within an ecosystem. This variable helps in understanding population density, dominance patterns, and ecological balance among vertebrate groups. Variations in species abundance often indicate changes in habitat quality, resource availability, and environmental disturbances.

Distribution patterns of vertebrate species are also analysed as an essential biodiversity variable. Species distribution patterns provide information regarding the spatial occurrence of vertebrates across different habitats and ecological regions. Distribution analysis helps identify endemic species, habitat specialists, migratory species, and vulnerable populations within the Western Ghats, Vidarbha, and the Konkan Coast ecosystems.[22,23]

Environmental Variables

The study includes environmental variables to understand the ecological conditions that influence vertebrate biodiversity and habitat suitability. Habitat type is one of the major environmental variables considered in the research. Different habitat types such as evergreen forests, dry deciduous forests, mangroves, wetlands, grasslands, and coastal ecosystems support distinct vertebrate communities and ecological interactions.

Vegetation cover is another significant environmental variable because vegetation directly affects habitat availability, food resources, shelter, breeding grounds, and ecological stability. Areas with dense, diverse vegetation generally support higher vertebrate diversity than degraded or fragmented habitats.

Rainfall and climatic conditions are also examined as key environmental variables that influence biodiversity distribution and ecosystem functioning. Climatic factors such as temperature, humidity, and precipitation determine habitat productivity, seasonal migration, breeding cycles, and species adaptation patterns across different ecological regions of Maharashtra.[24,25]

Anthropogenic Variables

Anthropogenic variables refer to human-induced factors that affect vertebrate biodiversity and ecosystem stability. Urbanisation is a major anthropogenic variable in the study because rapid urban expansion often leads to habitat fragmentation, pollution, and the loss of natural ecosystems. Urban growth particularly affects wildlife populations in ecologically sensitive and coastal regions.

Deforestation is another key anthropogenic driver of biodiversity decline in Maharashtra. Forest clearance for agriculture, infrastructure development, mining, and settlement expansion reduces habitat availability and disrupts ecological balance within forest ecosystems.

Industrialisation also contributes significantly to environmental degradation through pollution, land-use change, and habitat destruction. Industrial activities near forests and coastal regions negatively affect both terrestrial and aquatic vertebrate species.

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Tourism pressure is also considered because unregulated tourism in biodiversity-rich areas can cause habitat disturbance, waste generation, noise pollution, and increased human interference. Ecologically sensitive regions such as the Western Ghats and coastal ecosystems are particularly vulnerable to tourism-related environmental stress.[26,27]

Vertebrate Groups Considered

This study focuses on major vertebrate groups inhabiting Maharashtra's ecosystems to comparatively analyse biodiversity patterns, ecological adaptations, and conservation status across the Western Ghats, Vidarbha, and the Konkan Coast. Vertebrates are highly significant in ecological studies because they occupy different trophic levels, support ecosystem functioning, and indicate environmental health and habitat stability. The study includes mammals, birds, reptiles, amphibians, and fishes, which collectively represent diverse ecological niches and habitat associations. We selected these vertebrate groups for their ecological importance, conservation relevance, and sensitivity to environmental and anthropogenic changes across ecosystems.

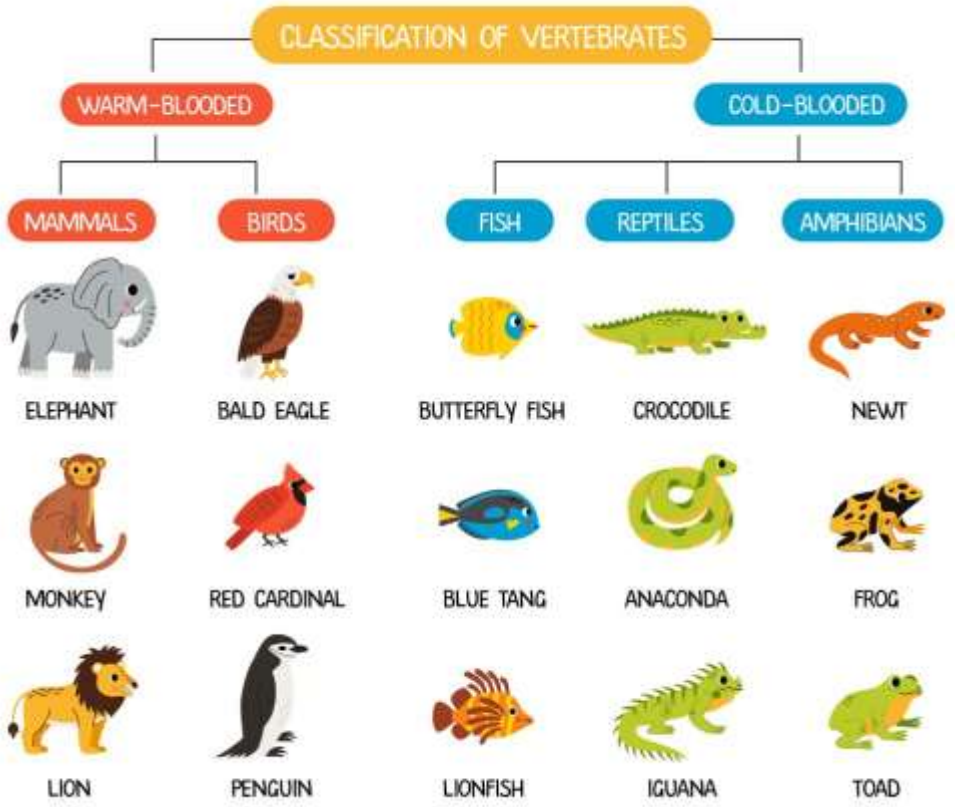


Figure 2: Classification of vertebrates

Mammals

Mammals constitute one of the most ecologically significant vertebrate groups included in the study. Maharashtra supports a wide variety of mammalian species, from large carnivores and herbivores to small mammals, inhabiting forests, grasslands, wetlands, and urban ecosystems. Mammals play an important role in maintaining ecological balance through grazing, seed dispersal, predation, and trophic regulation. The dry deciduous forests of Vidarbha are particularly important for large mammals such as tigers, leopards, deer, sloth bears, and wild boars. Protected areas, including Tadoba Andhari Tiger Reserve, support rich mammalian diversity and contribute significantly to the state's wildlife conservation efforts. Habitat quality, prey availability, forest connectivity, and human disturbance strongly influence mammalian diversity.[28]

Birds

Birds are another major vertebrate group considered in the study because of their high ecological diversity and widespread distribution across ecosystems. Maharashtra contains numerous resident and migratory bird species inhabiting forests, wetlands, coastal regions, grasslands, and urban green spaces. Birds serve as important ecological indicators because they respond rapidly to environmental changes and habitat disturbances. The Western Ghats and Konkan Coast are particularly rich in avian diversity because of dense vegetation, abundant water, and favourable climate. Coastal wetlands and estuaries support migratory birds during seasonal movements, while forest ecosystems provide nesting and feeding habitats for endemic and insectivorous species. Habitat fragmentation, pollution, urbanisation, and climate-related ecological changes affect bird diversity.[29]

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Reptiles

Reptiles form an essential component of vertebrate biodiversity within Maharashtra's ecosystems. The state supports diverse reptilian fauna, including snakes, lizards, turtles, and crocodilians, in forests, wetlands, rocky landscapes, mangroves, and coastal habitats. Reptiles are ecologically important because they shape food-chain dynamics and help regulate populations of insects and small vertebrates. The Western Ghats ecosystem is especially known for reptilian endemism due to its humid climate and complex forest habitats. Many reptile species are highly sensitive to habitat degradation, environmental pollution, and climatic variations. Human activities such as deforestation, illegal wildlife trade, road development, and urban expansion pose significant threats to reptilian biodiversity across Maharashtra.[30]

Amphibians

Amphibians are among the most environmentally sensitive vertebrate groups studied. Frogs, toads, and salamander-like species commonly inhabit moist habitats such as forests, wetlands, streams, and marshes. Amphibians are widely recognised as biological indicators because their permeable skin and dual aquatic-terrestrial life cycle make them highly vulnerable to environmental changes and habitat disturbances. The Western Ghats ecosystem has exceptionally high amphibian diversity and endemism, particularly in forest streams and high-rainfall regions. Habitat loss, water pollution, climate change, and changes in hydrological conditions severely affect amphibian populations. Conserving them is ecologically important for maintaining food webs and ecosystem balance.[31]

Fishes

Fish diversity forms a major component of aquatic biodiversity within the selected ecosystems. Maharashtra's rivers, estuaries, mangroves, wetlands, and coastal marine ecosystems support a wide variety of freshwater and marine fish species. The Konkan Coast ecosystem is particularly significant for fish diversity because estuarine and coastal habitats support the breeding, feeding, and migratory activities of aquatic organisms. Fishes contribute substantially to ecological productivity, nutrient cycling, and aquatic food chains. River flow, water quality, vegetation, and seasonal climatic conditions influence freshwater fish species, while coastal ecosystem dynamics affect marine species. Anthropogenic pressures such as overfishing, industrial pollution, dam construction, habitat degradation, and coastal development have increasingly threatened fish diversity and aquatic ecosystem stability in Maharashtra.[32]

Sampling Framework and Ecosystem Comparison

The present study's sampling framework uses a comparative ecosystem approach to evaluate vertebrate biodiversity and conservation status across ecologically distinct regions of Maharashtra. The framework focuses on three major ecosystems, namely the Western Ghats, Vidarbha, and the Konkan Coast, which collectively represent forest, dry deciduous, and coastal ecological systems within the state. These ecosystems were selected to ensure ecological diversity and to facilitate systematic comparison of vertebrate distribution, habitat characteristics, environmental conditions, and conservation challenges. The comparative framework identifies similarities and differences in biodiversity patterns across multiple habitat types while examining how anthropogenic activities affect ecological stability and wildlife conservation.

The study selects ecosystems based on ecological significance, biodiversity richness, habitat diversity, and conservation relevance. The Western Ghats ecosystem was selected because it is internationally recognised as a biodiversity hotspot with exceptionally high endemism and species richness. The region contains evergreen and semi-evergreen forests that support diverse vertebrate populations, particularly amphibians, reptiles, and birds. The Western Ghats' climate, including heavy rainfall, moderate temperatures, and dense vegetation cover, creates favourable conditions for wildlife survival and habitat stability. However, increasing human activities such as deforestation, tourism, road construction, and agricultural expansion have intensified environmental pressure on this ecosystem, making it highly relevant for comparative conservation analysis.

We selected the Vidarbha ecosystem because it represents the dry deciduous forest landscape of eastern Maharashtra and supports significant populations of large mammals and associated wildlife species. Vidarbha's ecological structure differs considerably from the Western Ghats because of lower rainfall, seasonal climatic variability, and relatively open forest cover. Despite these conditions, the region plays an important role in wildlife conservation, particularly for apex predators such as tigers and leopards. The ecosystem also faces serious conservation challenges from mining, habitat fragmentation, forest dependency, and human-wildlife conflict. A comparative analysis of Vidarbha allows the study to assess how dry forest ecosystems maintain biodiversity amid increasing ecological and anthropogenic stress.

The Konkan Coast ecosystem represents Maharashtra's coastal and marine ecological zone. This ecosystem includes mangroves, estuaries, wetlands, coastal forests, and marine habitats that support a wide range of aquatic and terrestrial vertebrates. The Konkan Coast is ecologically important due to its fish diversity, migratory bird populations, and coastal ecosystem services. Coastal habitats also perform critical ecological functions, including shoreline protection, nutrient cycling, and support for aquatic organism breeding. However, rapid urbanisation, industrialisation, tourism development, and pollution have increasingly threatened coastal biodiversity and habitat quality. Including the Konkan Coast in the comparative framework enables a broader understanding of biodiversity variation between terrestrial and coastal ecosystems.

The sampling framework additionally includes selected protected areas for detailed conservation analysis. Protected areas serve as important ecological units for biodiversity conservation because they preserve habitats, maintain wildlife populations, and support ecosystem stability. The study examines the role and

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effectiveness of protected areas in conserving vertebrate diversity within Maharashtra's selected ecosystems

Tadoba Andhari Tiger Reserve

Tadoba Andhari Tiger Reserve, located in the Vidarbha region, is one of the most important protected areas selected for the study. The reserve consists primarily of dry deciduous forest habitat and supports rich mammalian biodiversity, including tigers, leopards, sloth bears, wild dogs, deer, and numerous bird species. Tadoba is ecologically significant because it represents one of India's major tiger conservation landscapes and contributes substantially to predator conservation and forest ecosystem management. The reserve also provides insight into ecological relationships between predators, prey species, vegetation structure, and habitat connectivity. However, increasing tourism pressure, expanding human settlements, dependence on forest resources, and habitat fragmentation continue to create conservation challenges in the region.[33]

Sanjay Gandhi National Park

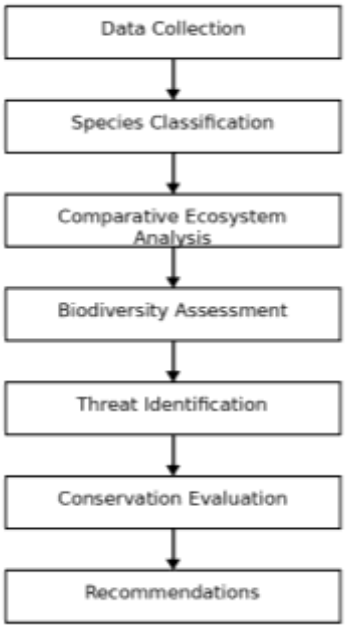
Sanjay Gandhi National Park, located near Mumbai within the Western Ghats ecological influence zone, was also selected for conservation assessment. The park represents an important urban forest ecosystem that supports diverse vertebrate fauna despite its proximity to densely populated urban areas. The protected area contains forests, wetlands, rocky terrains, and freshwater habitats that support mammals, birds, reptiles, amphibians, and insects. Sanjay Gandhi National Park is particularly significant because it demonstrates the role of protected urban ecosystems in biodiversity conservation and ecological sustainability. The park faces conservation challenges associated with urban encroachment, pollution, habitat fragmentation, and increasing human-wildlife interactions. Comparative analysis of this protected area provides understanding of conservation management within urban ecological settings[34]

Table 2: Ecosystem and dominant vertebrates

Ecosystem	Habitat Type	Key Protected Area	Dominant Vertebrates
Western Ghats	Evergreen Forest	Sanjay Gandhi National Park	Amphibians, Birds
Vidarbha	Dry Deciduous Forest	Tadoba Andhari Tiger Reserve	Tigers, Leopards
Konkan Coast	Coastal and Mangrove Ecosystem	Coastal Wetlands	Fish, Migratory Birds

Methods of Biodiversity Assessment

The study uses a systematic, comparative approach to assess vertebrate biodiversity in Maharashtra's ecosystems using secondary ecological data from sources such as scientific publications and biodiversity databases. Key methods include the species inventory method, which systematically documents vertebrate species, helps identify endemic and threatened species, and supports habitat classification. The comparative assessment evaluates biodiversity patterns across distinct ecosystems, focusing on species richness, abundance, and ecological diversity while examining each ecosystem's ecological significance. Furthermore, the ecological interpretation analyses how environmental factors and anthropogenic threats affect biodiversity, identifying major conservation challenges. Overall, the study develops a comprehensive framework for evaluating biodiversity and formulating region-specific conservation strategies for sustainable management.[35,36]



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Biodiversity Indices Used

Biodiversity indices are crucial tools in ecological studies for assessing species diversity, ecological stability, and habitat complexity. This study uses these indices to compare vertebrate diversity across the Western Ghats, Vidarbha, and the Konkan Coast ecosystems of Maharashtra, enabling quantitative assessments of species richness, distribution, dominance patterns, and ecological variation among habitats. Their application allows for systematic comparisons of vertebrate assemblages and aids in interpreting ecological conditions and conservation status

Species richness [37]

Species richness is a fundamental measure of biodiversity, indicating the total number of species in a specific ecosystem. This study assesses vertebrate species richness in Maharashtra, highlighting its role in evaluating biodiversity and ecological stability. Ecosystems with high species richness, such as the Western Ghats and Konkan Coast, are biologically productive because of their varied habitats. The Shannon–Wiener Diversity Index further assesses species diversity by accounting for species evenness, with higher values reflecting a more balanced species distribution and greater ecological diversity.

The index is represented mathematically as follows:

$$H' = -\sum p_i \ln\, p_i$$

In this equation, p_i represents the proportion of individuals of a particular species relative to the total number of individuals in the ecosystem. The Shannon–Wiener Index is widely used in biodiversity studies because it provides a more comprehensive understanding of ecological complexity and species composition. In this study, we apply the index to compare vertebrate diversity across the Western Ghats, Vidarbha, and the Konkan Coast ecosystems. The index helps determine ecosystem stability, habitat quality, and ecological resilience within different environmental conditions.

Simpson's Diversity Index[38]

Simpson's Diversity Index is a key biodiversity measure that assesses the likelihood that two randomly selected individuals from a habitat belong to different species. It helps assess species dominance and ecological concentration: higher values indicate greater biodiversity and lower species dominance, while lower values suggest ecological imbalance with dominance by fewer species.

Comparative Ecological Analysis

Comparative ecological analysis is crucial for biodiversity assessment, focusing on biodiversity indices, species distribution, and habitat characteristics across the Western Ghats, Vidarbha, and the Konkan Coast. This approach reveals variations in ecological stability, habitat quality, and vertebrate diversity. It also examines relationships between biodiversity and environmental factors such as rainfall and vegetation cover, as well as anthropogenic impacts like urbanisation and pollution. The study identifies biodiversity hotspots and conservation challenges in Maharashtra and uses these analyses to develop effective conservation strategies for sustainable vertebrate management.

Data Analysis Techniques

The study utilises various analytical techniques to assess vertebrate biodiversity, ecological variation, and conservation status in Maharashtra's ecosystems. Key methods include comparative statistical analysis, which evaluates biodiversity differences across regions and reveals how environmental factors influence species populations and habitat stability. Percentage analysis simplifies biodiversity data representation, focusing on species composition across ecosystems. Ecological interpretation connects species diversity to environmental variables, emphasising the impact of human activities on biodiversity. Graphical representations, such as bar graphs and pie charts, enhance data clarity. Overall, these methods provide a comprehensive framework for understanding biodiversity trends and informing conservation strategies in Maharashtra.

Conservation Assessment Framework

This study's conservation assessment framework evaluates vertebrate biodiversity across selected ecosystems in Maharashtra, focusing on the effectiveness of protected areas, ecological threats, and habitat vulnerability. It emphasises the role of protected areas, such as Tadoba Andhari Tiger Reserve, in conserving biodiversity by preserving habitats and protecting wildlife. The framework also assesses conservation policies, forest management, anti-poaching measures, and community involvement. Major threats to biodiversity include deforestation, urbanization, pollution, and climate change, which impact species distribution and habitat stability. Habitat vulnerability analysis identifies at-risk ecosystems, supports region-specific conservation strategies, and promotes sustainable biodiversity management. Ultimately, the framework aims to strengthen conservation planning and address ecological concerns to support long-term ecosystem sustainability.[39]

RESULTS AND FINDINGS

Comparative Vertebrate Biodiversity Across Ecosystems

The comparative assessment of vertebrate biodiversity across the Western Ghats, Vidarbha, and the Konkan Coast reveals considerable ecological variation in species richness, habitat associations, and biodiversity composition. These ecosystems differ significantly in climate, vegetation structure, topography, water availability, and anthropogenic influence, all of which shape vertebrate diversity and ecosystem functioning. The Western Ghats exhibit exceptionally high biodiversity due to dense forest cover, humid climate, and habitat heterogeneity, while Vidarbha supports rich mammalian diversity within dry deciduous forest ecosystems. The Konkan Coast, characterised by mangroves, estuaries, wetlands, and marine habitats, supports substantial fish diversity and migratory bird populations. Comparative biodiversity analysis demonstrates that each

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ecosystem contributes uniquely to Maharashtra's overall vertebrate diversity and ecological stability.

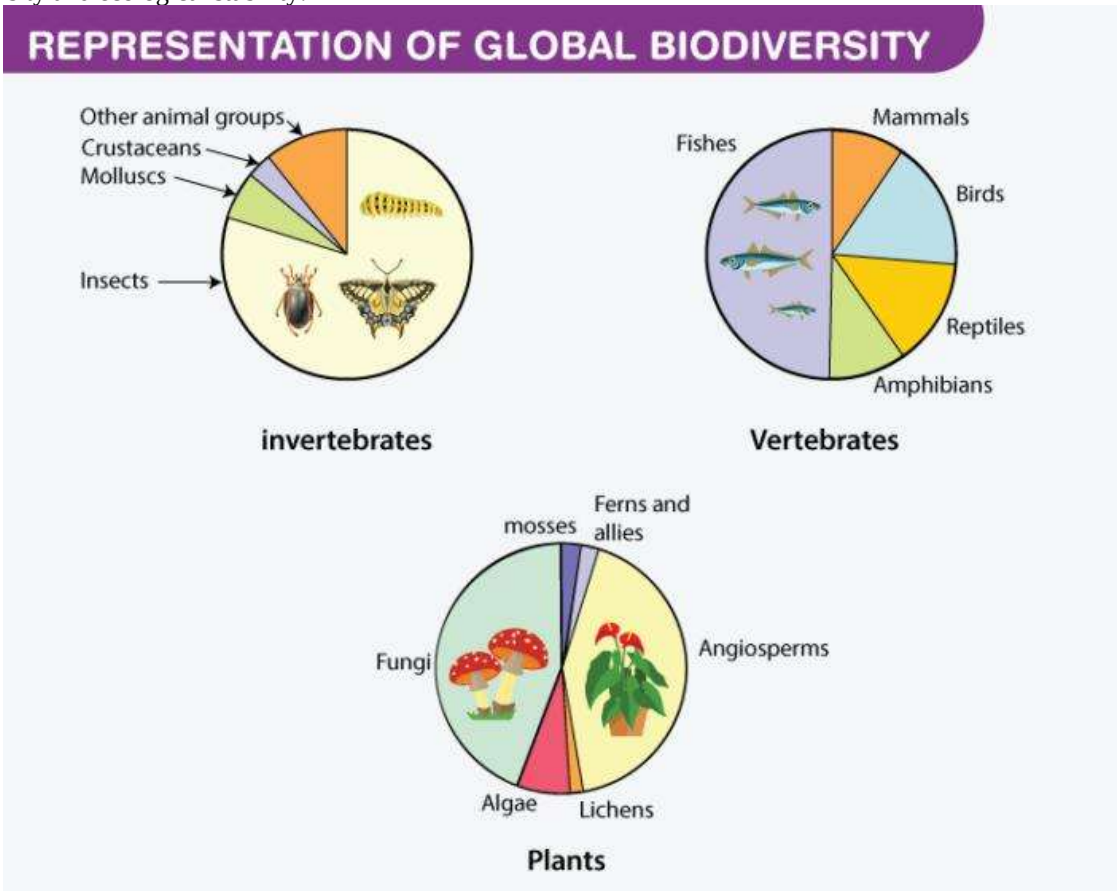


Figure 3: Global Biodiversity

Table 3 : Comparative Vertebrate Diversity Across Ecosystems

Vertebrate Group	Western Ghats	Vidarbha	Konkan Coast
Mammals	92	78	41
Birds	315	248	286
Reptiles	118	74	52
Amphibians	95	34	27
Fishes	146	89	328

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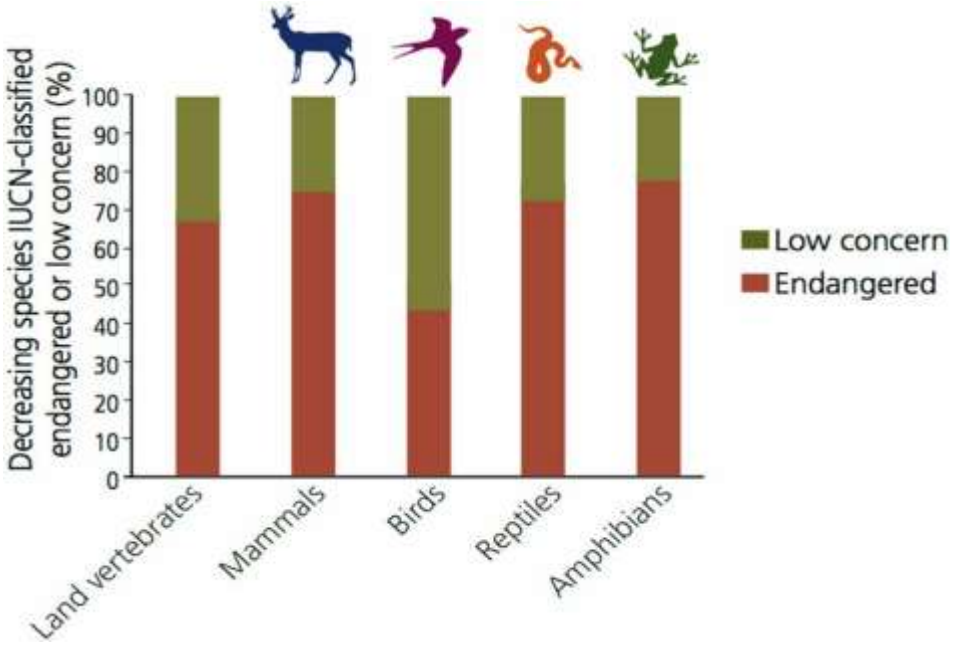


Figure 4: Ecosystem species-wise comparison

Mammalian Biodiversity

Mammalian diversity varies across ecosystems due to forest structure, climate, prey availability, and habitat connectivity. The Western Ghats have high diversity due to dense forests, rainfall, and habitat complexity, hosting species like leopards, Indian gaurs, and macaques. Vidarbha, notably in areas like Tadoba Andhari Tiger Reserve, has significant diversity with species such as tigers and sloth bears but faces threats from habitat fragmentation and human conflict. In contrast, the Konkan Coast supports lower diversity, featuring species like otters and bats due to urbanization and tourism impacting habitats. Despite these challenges, mangrove ecosystems still support essential mammalian species.

Table 4 : Comparative Mammalian Diversity

Ecosystem	Major Mammalian Species	Dominant Habitat
Western Ghats	Leopard, Gaur, Macaque	Evergreen Forest
Vidarbha	Tiger, Sloth Bear, Deer	Dry Deciduous Forest
Konkan Coast	Otter, Bats, Rodents	Mangroves and Coastal Wetlands

Avian Diversity

Bird diversity is notably high in three ecosystems: the Western Ghats, the Konkan Coast, and Vidarbha. The Western Ghats, with its dense forests and varied altitudes, support numerous endemic species, including hornbills and flycatchers, that breed there. The Konkan Coast supports migratory birds such as flamingos and egrets due to its coastal habitats and wetlands. Vidarbha has moderate avian diversity, with species like peafowl and eagles that rely on forests and water bodies, but it faces threats from deforestation and habitat degradation.

Table 5 : Comparative Avian Diversity

Ecosystem	Dominant Bird Groups	Ecological Characteristics
Western Ghats	Endemic Forest Birds	Dense vegetation and forest canopy
Vidarbha	Woodland and Grassland Birds	Dry forests and reservoirs
Konkan Coast	Migratory Coastal Birds	Wetlands and estuarine habitats

Reptilian Diversity

Reptilian diversity in the Western Ghats is high due to favorable humidity and ecological complexity, housing numerous endemic species of snakes, lizards, geckos, and turtles in varied habitats. In contrast, Vidarbha has moderate diversity, with species such as cobras and pythons in dry forests. The Konkan Coast has lower diversity but includes important coastal reptiles such as sea turtles. However, habitat degradation and pollution threaten reptilian biodiversity across these regions.

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Table 6: Comparative Reptilian Diversity

Ecosystem	Dominant Reptiles	Habitat Type
Western Ghats	Geckos, Tree Snakes, Lizards	Humid Forest Ecosystem
Vidarbha	Cobras, Monitor Lizards	Dry Forest and Rocky Habitat
Konkan Coast	Sea Turtles, Aquatic Snakes	Coastal and Mangrove Habitat

Amphibian Diversity

Amphibian diversity varies significantly across different ecosystems. The Western Ghats boast high diversity due to abundant rainfall and unique forest habitats, with many endemic species. Vidarbha has lower diversity because of seasonal rainfall and habitat fragmentation, and amphibians are found mainly near seasonal wetlands. The Konkan Coast features moderate diversity linked to wetlands and mangroves, although pollution and habitat changes threaten these populations.

Table 7: Comparative Amphibian Diversity

Ecosystem	Major Amphibian Habitat	Amphibian Diversity Level
Western Ghats	Forest Streams and Wetlands	Very High
Vidarbha	Seasonal Ponds and Forest Pools	Moderate
Konkan Coast	Coastal Wetlands and Marshes	Moderate

Fish diversity

Fish diversity is notably high in the Konkan Coast ecosystem because its rich marine, estuarine, and mangrove habitats support both freshwater and marine species. These areas serve as significant breeding grounds for various aquatic organisms, enhancing biodiversity. The Western Ghats are home to endemic freshwater fish in rivers and wetlands, where water quality and forest cover are crucial to aquatic biodiversity. In contrast, Vidarbha has moderate fish diversity, which human activities like dam construction and pollution affect, impacting freshwater species in its rivers, lakes, and reservoirs.

Table 8: Comparative Fish Diversity

Ecosystem	Major Aquatic Habitat	Dominant Fish Type
Western Ghats	Hill Streams and Rivers	Freshwater Endemic Fish
Vidarbha	Lakes and Reservoirs	Freshwater Riverine Fish
Konkan Coast	Estuaries and Coastal Waters	Marine and Estuarine Fish

Species Richness and Diversity Analysis

Species richness and biodiversity indices are vital for assessing ecosystem diversity and stability. This study compares vertebrate biodiversity across the Western Ghats, Vidarbha, and the Konkan Coast in Maharashtra using indices such as the Shannon–Wiener and Simpson Diversity Indices. Each ecosystem's unique climate, vegetation, and human impact shape species distribution. The Western Ghats feature dense forests, Vidarbha consists of dry deciduous forests, and the Konkan Coast includes rich coastal ecosystems. This comparative analysis elucidates ecological differences and conservation needs among these regions.

Table 9: Species Richness and Diversity Indices Across Ecosystems

Ecosystem	Shannon Index	Simpson Index	Species Richness
Western Ghats	4.36	0.93	766
Vidarbha	3.81	0.87	523
Konkan Coast	4.08	0.91	734

Simpson Diversity Index Results

Simpson Diversity Index is another important ecological indicator used to evaluate species dominance and biodiversity concentration within ecosystems. Higher Simpson index values indicate greater species diversity and lower dominance by individual species, whereas lower values suggest ecological imbalance and species concentration. The index therefore provides insight into ecological uniformity and habitat stability across ecosystems.

The Western Ghats recorded the highest Simpson index value of 0.93, indicating very high ecological diversity and low species dominance within the ecosystem. The result reflects a balanced distribution of vertebrate species across multiple habitat types, including evergreen forests, wetlands, hill streams, and forest canopies. The high Simpson index shows that no single vertebrate group dominates the ecosystem, indicating strong ecological balance and habitat complexity. Diverse vegetation structure and climatic stability further contribute to ecological resilience and species coexistence within the Western Ghats.

The Konkan Coast recorded a Simpson index value of 0.91, reflecting substantial ecological diversity and species distribution within coastal ecosystems. The high value is strongly

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associated with aquatic biodiversity and migratory avian populations inhabiting mangroves, estuaries, wetlands, and marine habitats. Fish diversity contributes significantly to the ecosystem's ecological productivity. Seasonal variation in migratory species also enhances the distribution of biodiversity and ecological complexity. The Simpson index suggests that coastal ecosystems continue to maintain considerable biodiversity despite increasing anthropogenic pressure and environmental degradation.

Vidarbha recorded a Simpson index value of 0.87, indicating moderate ecological diversity and relatively greater species dominance than the other ecosystems. Mammalian species dominate biodiversity patterns in the region because extensive dry deciduous forests and protected habitats support apex predators and herbivores. However, lower habitat heterogeneity and seasonal climatic limitations reduce ecological diversity in comparison with the Western Ghats and Konkan Coast. Anthropogenic activities, including deforestation, habitat fragmentation, and mining, have also affected species distribution and ecological balance.

Distribution Patterns of Vertebrate Species

Ecological conditions, habitat structure, climate, vegetation, water availability, and human activities significantly influence vertebrate species distribution in Maharashtra. Various ecosystems, including the Western Ghats and Konkan Coast, harbor distinct vertebrate communities adapted to their specific environments. Insights into species distribution reveal ecological adaptations, habitat preferences, and conservation needs. Furthermore, ecological interactions such as food availability and habitat connectivity shape the distribution patterns of mammals, birds, reptiles, amphibians, and fishes, with higher diversity in more stable, heterogeneous ecosystems. Urbanisation and environmental degradation threaten these distribution patterns.

Forest Ecosystems

Forest ecosystems in Maharashtra are crucial for vertebrate biodiversity, particularly in the Western Ghats and Vidarbha. The humid climate and habitat complexity of the Western Ghats contribute to high vertebrate diversity. Key mammals include leopards, gaurs, and monkeys, which thrive in these forests because of ample shelter and food. Bird diversity is also significant, supported by fruit-bearing trees and wetlands, with notable species like hornbills and parakeets. Additionally, reptiles and amphibians are well-adapted to these ecosystems, finding favorable conditions in streams and moist habitats, leading to a high level of endemism linked to ecological isolation and specialized conditions.

Ecological Adaptations Observed

Ecological adaptations are vital for the survival and success of vertebrate species in Maharashtra's diverse ecosystems, including the Western Ghats, Vidarbha, and the Konkan Coast. Varying climatic conditions and habitat structures shape these adaptations in mammals, birds, reptiles, amphibians, and fish. In the Western Ghats, high rainfall and humidity foster specialised adaptations in amphibians, while mammals and reptiles utilise forest microclimates. Vidarbha's dry deciduous forests promote adaptations for heat and water scarcity among species like tigers and leopards. The Konkan Coast supports coastal species adapted to salinity and tidal influences. However, anthropogenic impacts and climate change are increasingly threatening these ecological adaptations and species survival. Shifting climate patterns affect breeding cycles and habitat suitability, especially for species with specific climatic needs.

Habitat Specialisation

Habitat specialisation is a key ecological adaptation in Maharashtra, where vertebrate species occupy specific ecological niches dictated by environmental conditions and food resources. The Western Ghats show high habitat specialisation because of diverse forests and ecological isolation, with many endemic amphibians and reptiles. Arboreal mammals and birds in this region adapt to life in the forest canopy. In Vidarbha, habitat-specialist vertebrates, including tigers and leopards, thrive in extensive forests, while herbivores occupy open landscapes. The Konkan Coast supports species adapted to mangrove and estuarine ecosystems, with urban areas influencing vertebrate adaptability. Feeding adaptations reflect habitat conditions and include diverse strategies among mammals, birds, reptiles, and fish, crucial for ecological interactions and biodiversity stability.

Migration Behaviour

Migration behaviour is a crucial ecological adaptation among vertebrates, especially birds and fishes, allowing them to respond to seasonal environmental changes. The Konkan Coast serves as a vital migratory zone for various species, with coastal wetlands providing essential habitats. Birds such as flamingos and herons migrate seasonally to find food and suitable breeding conditions, while fish move between freshwater and marine environments in response to hydrological changes. Other vertebrates, including mammals and amphibians, move locally based on water availability and breeding needs. However, anthropogenic activities such as habitat fragmentation and climate change disrupt these migration patterns, affecting reproductive success and ecosystem stability. This situation highlights the importance of tailored conservation and habitat management strategies to protect these ecological relationships in Maharashtra

Deforestation.

Deforestation is a critical threat to vertebrate biodiversity in Maharashtra, driven by agriculture, infrastructure development, and mining. Tourism and agricultural encroachment have notably impacted the Western Ghats; vital habitats for endemic species face fragmentation, which diminishes ecological connectivity and genetic diversity. In Vidarbha, habitat loss from agricultural expansion and mining endangers large mammals like tigers and leopards, while the Konkan Coast suffers from mangrove destruction, affecting coastal ecosystems. Overall, deforestation reduces species

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richness, degrades habitats, and increases vulnerability to climate impacts.

Urbanization

Urbanisation in Maharashtra profoundly impacts vertebrate biodiversity. Rapid development leads to habitat loss, pollution, and fragmentation. The Western Ghats face increased urban pressure from tourism and residential growth, displacing forest-adapted species. In Vidarbha, moderate urbanisation affects biodiversity as settlements expand near forests, disrupting wildlife movement. The Konkan Coast, experiencing the most intense urbanisation, suffers significant ecological degradation, altering vertebrate distribution and reducing habitats for migratory species.

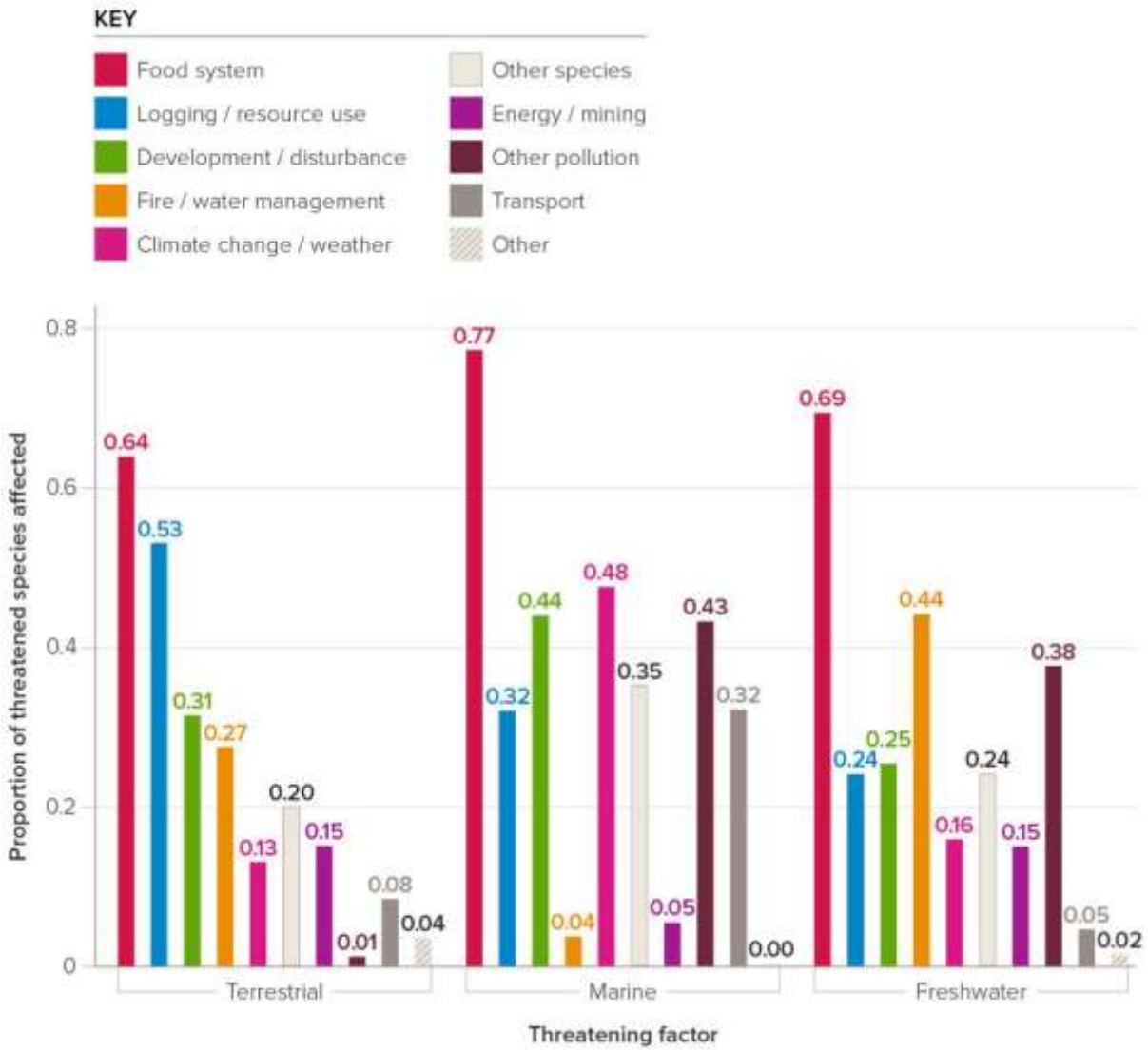


Figure 5: Indices of species affected

Industrial Expansion

Industrial expansion in Maharashtra is a major driver of environmental degradation and biodiversity loss. Activities such as mining, manufacturing, and thermal power generation drive habitat destruction and pollution, particularly in Vidarbha, where coal extraction affects dry deciduous forests and wildlife. The Konkan Coast faces severe ecological pressure from ports and petrochemical industries that affect mangroves and marine habitats. Coastal pollution harms fish diversity and disrupts habitats for birds and reptiles. While the Western Ghats are less industrialized, ongoing infrastructure projects threaten ecological stability and endemic species.

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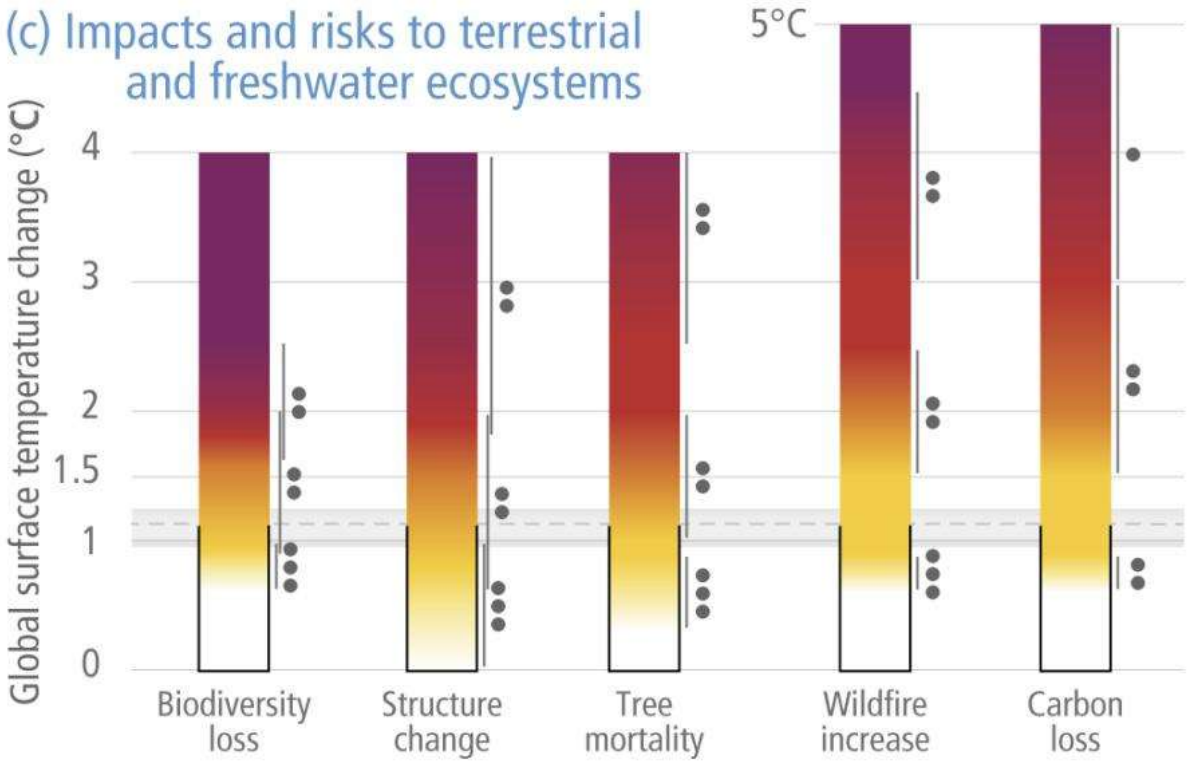


Figure 6: Impacts and risks to terrestrial and freshwater ecosystems

Conservation Status of Vertebrate Species

The conservation status of vertebrate species in Maharashtra indicates the health of its diverse ecosystems. Species in the Western Ghats, Vidarbha, and the Konkan Coast face threats from habitat degradation, climate change, and pollution. Assessing their status is crucial for identifying those at high extinction risk and directing conservation efforts. The Western Ghats are home to many endemic and threatened species, while Vidarbha's forests are key for large mammals. Coastal ecosystems support sensitive aquatic species and migratory birds threatened by human activities like deforestation and pollution. Overall, anthropogenic pressures heighten ecological vulnerability across these regions**.**

Major Findings of the Study

The study's major findings on vertebrate biodiversity in Maharashtra indicate significant ecological variation across the Western Ghats, Vidarbha, and the Konkan Coast. The Western Ghats showed the highest biodiversity because favourable conditions support a wide variety of mammals, birds, reptiles, and amphibians. The Konkan Coast followed, with diverse marine and coastal ecosystems that enhance species richness. Although Vidarbha has lower overall species richness, it is crucial for mammalian conservation, particularly at the Tadoba Andhari Tiger Reserve. The study shows how habitat heterogeneity, ecological connectivity, and anthropogenic pressures shape biodiversity patterns, affecting species distribution and conservation effectiveness across these ecosystems.

Summary

The study examines vertebrate biodiversity and conservation across Maharashtra's ecosystems: the Western Ghats, Vidarbha, and the Konkan Coast. It highlights significant ecological variation in species richness, habitat conditions, and conservation effectiveness. The Western Ghats show the highest vertebrate diversity, while the Konkan Coast has notable aquatic and avian diversity. Vidarbha is crucial for large mammals in dry deciduous forests. The study analysed key biodiversity indices and found that complex habitats support higher biodiversity. The study also discusses how habitat type and anthropogenic impacts, such as deforestation and pollution, shape species distribution and threaten biodiversity and ecosystem resilience. Conservation efforts in protected areas like Tadoba Andhari Tiger Reserve are significant but challenged by human pressures. The findings stress the need for habitat restoration and sustainable conservation strategies to safeguard Maharashtra's vertebrate biodiversity.

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