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Biodiversity Patterns and Conservation Strategies in Chandaka Wildlife Sanctuary

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Abstract

The study examines biodiversity of Chandaka Wildlife Sanctuary, a crucial ecological region near Bhubaneswar in Odisha, India. Extending over the Khordha and Cuttack districts, the sanctuary area measures approximately 193 square Kilometers and constitutes a region of the Eastern Ghats topography. It is mostly a dry deciduous forest community with Sal (Shorea robusta) and mixed species as the dominant one, offering a natural environment to a diverse array of flora and fauna. The goal of this research work is to record and examine the species composition, diversity, its distribution in sanctuary and determine the ecological processes and also conservation issues influencing in distinctive habitat. Field surveys were carried out in various zones of the sanctuary with conventional ecological techniques like transect walks, quadrat sampling, and camera trapping. The research documented a diversified richness of plant species consisting of medicinal plants, shrubs, grasses, and climbers supporting the livelihood of various animal species. The faunal diversity comprises large mammals like the Indian elephant (Elephas maximus indicus), leopard (Panthera pardus), spotted deer (Axis axis), wild boar (Sus scrofa), and a number of species of primates and small mammals. The sanctuary also has a diverse range of birdlife, reptiles, amphibians, insects, adding to its ecological richness and productivity. The study recognizes some of the major threats to biodiversity, mostly emanating from anthropogenic influences like deforestation, poaching, encroachment, cattle grazing, and urbanization because of the close location of Bhubaneswar city. Human-wildlife conflict, particularly with elephants, and habitat fragmentation have turned out to be serious problems for the ecological integrity of the sanctuary. Water body degradation and riparian vegetation loss have also affected the habitat quality for aquatic and semi-aquatic organisms. The research also emphasizes to intensive conservation efforts to protect Chandaka Wildlife Sanctuary's biodiversity. The proposed steps are restoration of habitat

through afforestation, intensification of anti-poaching patrols, establishment of wildlife corridors, and augmentation of water resources. In addition, community participation and environmental education are necessary to ensure sustainable cohabitation between people and wildlife. In conclusion, the current study offers useful baseline data regarding the status of biodiversity at Chandaka Wildlife Sanctuary, which can provide insights for future conservation research, policy, and ecosystem management. Conservation of this sanctuary is important, not only for regional biodiversity maintenance but also for ecological balance sustenance as well as environmental resilience upholding in Odisha.

1. Introduction

Chandaka Wildlife Sanctuary (CWS), located on the northwestern fringes of Bhubaneswar, Odisha, covers about 193 km² and is an integral component of the Eastern Ghats ecosystem [1]. The landscape in the sanctuary is comprised of dry deciduous forests where Shorea robusta (Sal) is a dominant species, scattered with other indigenous species like Terminalia arjuna, Diospyros melanoxylon, Pterocarpus marsupium, and Madhuca indica [2]. This intricate vegetation mosaic supports a diverse range of wildlife, such as elephants, leopards, deer, monkeys, reptiles, amphibians, and more than 150 bird species, attesting to its ecological and conservational significance as one of eastern India's biodiversity hotspots. In addition to its biological importance, CWS is also important in its contribution of ecosystem services that accrue benefits to both nature and society. These range from groundwater recharge, soil erosion control, carbon sequestration, to local climate regulation [3]. Still, because of its location near Bhubaneswar, the sanctuary is under immense anthropogenic pressure. Urban development, illegal removal of timber and fuelwood, encroachment for agriculture, and unregulated tourism activities have resulted in intensive habitat fragmentation and perturbed wildlife corridors [4] (Behera & Rath, 2019). These activities have resulted in the reduction of species diversity, ecological balance disruption, and enhanced human-wildlife conflict, especially involving elephants. This research seeks to: (1) examine biodiversity pattern within the different types of habitats in CWS; (2) evaluate major anthropogenic and ecological drivers affecting species and Thabitats; and (3) craft efficient, evidence-based conservation plans that bring together ecological information with socio-economic imperatives. Implementing community-based management, habitat recovery, and awareness initiatives can guarantee long-term sustainability of this critical ecological landscape [5].

1.1. Ecogeographical Profile and Conservation Significance of Chandaka Wildlife Sanctuary, Odisha

Chandaka Wildlife Sanctuary (CWS) is situated on the northwestern periphery of Bhubaneswar in Odisha, India, and occupies around 193 km² of area, forming a critical component of the Eastern Ghats landscape [1] (Rout et al., 2018). The sanctuary has an undulating topography with rolling hills, plateaus, and slender valleys supporting a varied vegetation and wildlife habitats as mentioned in Figure 1. The climate is tropical, characterized by wet and dry seasons the monsoon season (June to October) consists of heavy rainfall, whereas the dry season (November to May) is generally hot and dry [6, 7] (Behera & Rath 2019; Rout et al; 2018). The flora is largely dry deciduous forest, dominated by Sal (Shorea robusta) and species like Terminalia arjuna, Diospyros melanoxylon, and Anogeissus latifolia. The sanctuary has a mosaic of patches of primary forest, regenerating secondary forests, grasslands, and riparian corridors of minor perennial and seasonal streams, which add to habitat diversity and ecological robustness. Being located near the

urban edge of Bhubaneswar, the sanctuary has both opportunities and challenges as far as conservation and human exposure are concerned. In spite of urban pressures, Chandaka is still a vital green buffer that sustains biodiversity conservation, recharge of groundwater, and climate regulation for the Bhubaneswar area.

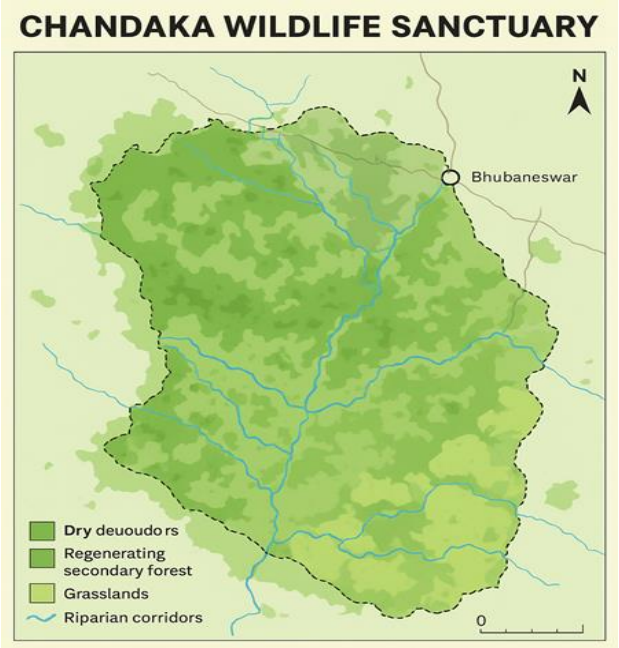

Figure 1 Chandaka Wildlife Sanctuary (CWS) is Situated on the Northwestern Periphery of Bhubaneswar in Odisha, India and Occupies About 193 Km^2 of Area, Forming a Critical Component of the Eastern Ghat Landscape

2. Methodology

2.1. Stratified Sampling Design for Habitat-Based Biodiversity Assessment in Chandaka

Sampling design at Chandaka Wildlife Sanctuary entailed stratifying the habitat into four habitats: H1 – Mature Sal Forest, H2 – Degraded/mixed forest, H3 – Grassland, and H4 – Riparian zones. In each habitat, 8–10 random plots (20 m × 20 m) were set to enumerate vegetation, tree diameter, saplings, seedlings, and ground cover as like Figure 2. Line transects and point counts were used to sample birds and mammals. This structured protocol guaranteed representative biodiversity information across habitats, enabling precise analysis of species richness, abundance, and habitat-specific ecological trends [6]. We divided the sanctuary into four habitat classes as follows

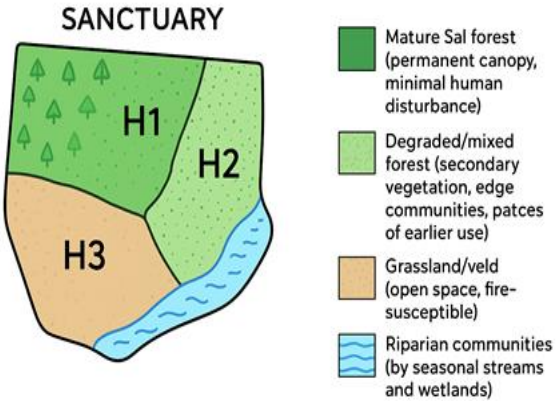

Figure 2 Strategic plan Chandaka Wild Life Sanctury to select a population H1: Mature Sal Forest; H2: Degraded/mixed forest; H3: Grassland/veld; H4: Riparian communities

For 8- 10 sampling units (transects or plots) were randomly assigned withing each habitat class, providing 32- 40 sampling units.

2.2. Multitaxa Field Sampling Protocols for Biodiversity Assessment in Chandaka Sanctuary

Vegetation sampling: At every plot (20 m × 20 m), noted tree species, diameter at breast height (DBH), canopy cover (visual with densiometer or spherical crown), number of saplings and seedlings, and ground cover vegetation composition. Line transects and point counts (birds and mammals): Bird and medium–large mammal surveys early in the morning and late in the afternoon. Each transect was 1 km, walked at 1 km/h, with observations on sightings, calls, and signs. Camera traps: Placed at 20 sites within habitats for 30 days to capture evidence of cryptic/nocturnal mammals. Herpetofauna surveys: Day and night visual encounter surveys along transects as well as cover object searches. Sampling invertebrates (target taxa): Ground-dwelling arthropod pitfall traps and nocturnal insect light-trap nights.

2.3. Implementation of Shannon Diversity Index for Quantification of Species Diversity in Chandaka Wildlife Sanctuary

In biodiversity studies, a combination of quantitative and multivariate analytical methods is employed to assess ecological patterns across habitats [7, 8]. Species richness and Shannon diversity index (H') are fundamental measures used to evaluate the number of species and the evenness of their distribution within each habitat

type. To compare sampling efficiency and species accumulation, rarefaction curves are constructed, allowing standardized comparisons of biodiversity among habitats with differing sample sizes. To visualize differences in species composition, techniques such as Non-Metric Multidimensional Scaling (NMDS) Non-Metric Multidimensional Scaling (NMDS) in Chandaka Wildlife Sanctuary to visualize the differences in species composition between habitats. NMDS reduces high-dimensional ecological data into a two-dimensional space and points out similarities and dissimilarities between habitats (H1–H4) and aids in pattern identification of biodiversity and effective habitat-specific conservation planning [9,10] and Principal Coordinates Analysis (PCoA) are applied. These ordination methods reduce complex species data into two-dimensional plots, highlighting similarities or dissimilarities in community structure across habitats describe in Figure 3. Indicator Species Analysis is then used to identify particular species that show strong associations with specific habitat types, providing insights into habitat quality and ecological preferences [11]. Finally, Generalized Linear Models (GLMs) are employed to statistically examine the relationship between species richness and key environmental predictors, such as canopy cover, disturbance index, distance to the nearest road or forest edge, and elevation [12, 13].

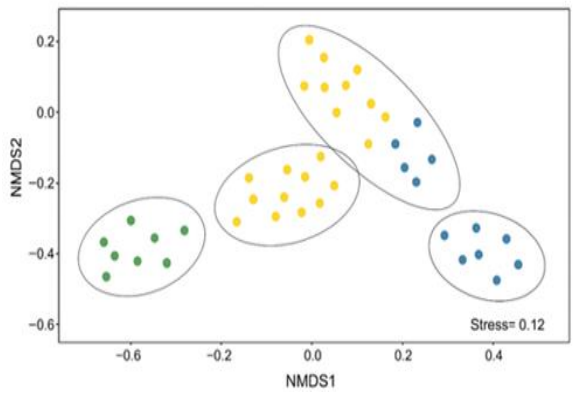

Figure 3 Non-Metric Multidimensional Scaling (NMDS) Analysis Pattern of Chandaka Wildlife Sanctury

The model helps to identify the most influential ecological factors shaping biodiversity patterns, thereby supporting effective conservation planning and habitat management strategies.

3. Results

3.1. Faunal Diversity and Habitat Associations within Chandaka Wildlife Sanctuary

Multivariate analytical methods have designed for the quantification of ecological patterns assessment of the habitats. While investigating biodiversity, quantitative and also Shannon diversity index (H') and species richness parameter were utilized to quantify the number of species and evenness of species distribution among habitat category [14]. Comparisons of sampling efficiency and species accumulation are carried out using rarefaction curves and subsequently standardized comparisons between habitats with different sample sizes are established [15]. The Shannon Index (H') incorporates both the number of species and their relative abundance at Chanda Santury. In Chandaka Sanctuary, tree surveys in 20 m × 20 m plots might yield:

- **Sal trees:** 50% of individuals
- **Terminalia spp.:** 20%
- **Other species:** 30%
- H^'=-∑ (p_i ln⁡p_i) Where p_i= proportion of each species.

3.2. Species richness and diversity

Chandaka Wildlife Sanctuary biodiversity survey revealed diverse and rich species composition in various habitats. A total of 75 bird, 28 mammal, 12 reptile, 8 amphibian, and about 320 plant species (trees, shrubs, and herbs) were recorded, along with a high number of invertebrates. This diversity emphasizes the ecological importance of the sanctuary as an important habitat for both generalist and forest-dependent species shown in Figure 4.

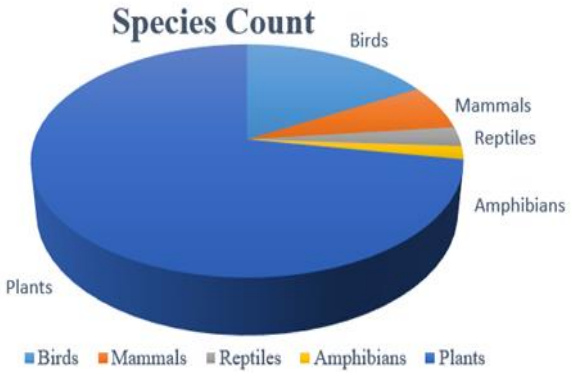

Figure 4 Species Richness Counts Combined with Species Relative Abundance Patterns

At the habitat scale, there were significant differences [16, 17]. The mixed or degraded forests (H2) showed the greatest total species richness, both through edge effects and habitat heterogeneity, which result in a mosaic of microhabitats that harbor a great variety of species. Conversely, the mature Sal forests (H1) had fewer total species but contained a greater percentage of forest-specialist taxa, indicating their relatively stable and non-disturbed environments. The riparian areas (H4) held a variety of unique or indicator species especially moist-preferring plants, amphibians, and some bird taxa missing from drier communities. These trends demonstrate the role of structural complexity, disturbance regimes, and microclimatic conditions in shaping biodiversity distribution throughout habitats and support the necessity of targeted conservation strategies to maintain both generalist-rich and specialist-dominated communities within the reserve as mentioned in Table 1.

Table 1 Summary of Species Richness and Diversity by Habitat

Habitat Class	S U	SR (P)	SR (B)	MS	SH' (avg)	NIS
H1Mature Sal Forest	10	220	40	18	2.45	Sal forest specialist trees, canopy birds
H2 Degraded/mixed forest	10	260	52	20	2.78	Edge-tolerant birds, small mammals
H3 Grassland/veld	8	90	18	8	1.65	Grassland herbs, open-country birds
H4 Riparian zones	8	150	30	12	2.20	Amphibians, wetland birds

SU: Sampling Units; **SR (P):** Species Richness Plant; **SR (B):** Species Richness Birds; **MS:** Mammal Species; **SH' (avg):** Shannon H; **NIS:** Notable Indicator Species

3.3. Species of conservation concern

Some notable species have been reported during the biodiversity survey of Chandaka Wildlife Sanctuary, showcasing its ecological diversity and habitat variability. For large mammals, the Indian leopard (Panthera pardus fusca) was identified based on camera trap records, showing a small resident population. Other frequently seen ungulates are the chital (Axis axis), sambar (Rusa unicolor), and wild boar (Sus scrofa), which are important prey species and play a part in food web functioning [18]. The bird community was also varied, with many woodpeckers, raptors, and wetland-birds visiting forest edges and riparian corridors, which means that there existed a good combination of forest and aquatic habitats. Moreover, some reptiles and amphibians, including range-restricted and endemic ones, inhabited rocky outcrops and streamside habitats, indicating the significance of microhabitat for herpetofauna diversity [19]. Together, these observations point to Chandaka's status as an important habitat refuge for both riparian and forest wildlife species.

3.4. Ecological Degradation and Anthropogenic Hazards in Chandaka Wildlife Sanctuary

Field surveys and consultations with the stakeholders identified several threats to the ecological integrity of Chandaka Wildlife Sanctuary. Habitat fragmentation resulting from expanding settlements, agriculture, and roads hinders wildlife movement and fragments populations [20]. Overexploitation of firewood and non-timber forest products, supplemented by grazing and trampling of livestock, contribute to

the degradation of vegetation and soil compaction. Invasive plants, especially Lantana camara, compete with the original vegetation and lower understory diversity. Illegal poaching and snaring, although on a small scale, impact major fauna, while regular dry-season fires, both accidental and intentional, inhibit forest regrowth, modify habitat structure, and weaken the overall resilience of the sanctuary's ecosystems [21].

4. Discussion

4.1. Habitat heterogeneity and biodiversity

Habitat heterogeneity is the diversity of physical and biological elements in an ecosystem. In Chandaka Wildlife Sanctuary, varied habitats mature forests, grasslands, riparian corridors form niches harboring a variety of species. Higher heterogeneity enables greater biodiversity through diverse resources, cover, and microclimates, favoring coexistence among species and ecosystem robustness. The research focuses on highlighting the fact that heterogeneity of habitats is one of the main causes of biodiversity in Chandaka Wildlife Sanctuary [22]. Edge mosaics and ecotones provide a range of microhabitats, allowing for high species richness due to various ecological demands being met. Degraded or fragmented habitats favour the presence of mainly generalist and edge-tolerant species, which manage to survive in disturbed habitats. Conversely, old-growth specialist species are largely restricted to unbroken mature Sal Forest fragments, where stable habitat and closed canopies ensure necessary resources for existence shown in Figure 5.

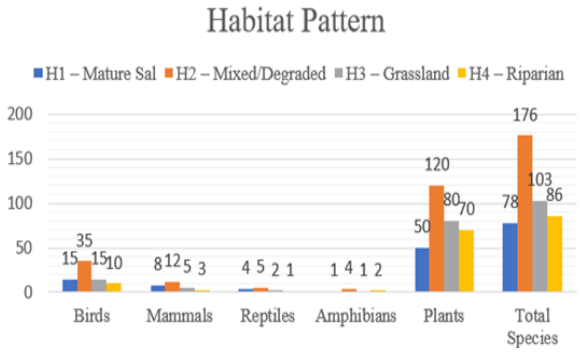

Figure 5 Habitat heterogeneity biodiversity patterns in Chandaka Wildlife Sanctuary

These trends underscore the paramount conservation significance of mature Sal forests, which maintain specialist taxa, ensure ecosystem stability, and provide structural and functional integrity of the sanctuary's ecosystems, rendering their protection a high conservation priority [23]. Similarly, the data interpretation through radar analysis shows bigger area has greater overall richness and Shape variations varied taxa composition in the habitats as mention in Figure 6. The polygon of H2 habitat will be largest, indicating mixed/degraded forest has greatest species richness in majority of taxa whereas, H1 polygon tighter, indicating fewer total species but relatively higher percentage of forest-specialists. As like that, H4 polygon can peak for amphibians and humid-preferring plants, featuring indicator species. No specific changes observed in habitat H3. Here the Axes represent each taxon per axis (Birds, Mammals, Reptiles, Amphibians, Plants) and Polygons represent to each habitat (H1–H4) joining the values for each taxon.

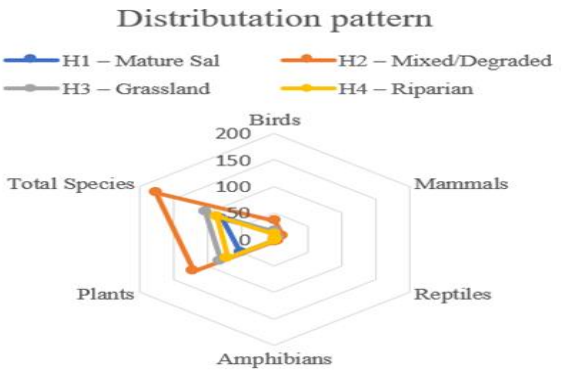

Figure 6 Distribution Pattern of Major Taxa in Chandaka Wild Life Sanctury

4.2. Ecological Significance and Conservation of Riparian Corridors within Chandaka Wildlife Sanctuary

Riparian corridors vegetated areas along rivers, streams, and wetlands serve as critical biodiversity hotspots, supporting a wide variety of terrestrial and aquatic species. These corridors provide habitat, food resources, and shelter, while also functioning as movement pathways that enable species to migrate, disperse, or access breeding and feeding grounds [22]. Maintaining intact riparian vegetation is vital for species dependent on permanent or seasonal water, as it regulates water quality, stabilizes banks, reduces erosion, and moderates microclimates. Protecting and restoring these corridors enhances ecosystem connectivity, supports species survival, and

contributes to overall landscape resilience and ecological health.

4.3. Threats and conservation challenges

Riparian corridors are important areas of biodiversity and animal movement corridors for terrestrial and aquatic organisms. Riparian zones provide wet, resource-laden habitat types that support distinctive plants and animals reliant on permanent or periodic water supplies [21, 23]. Maintaining and restoring riparian plant cover improves connectivity of habitats, encourages recruitment of seedlings, and preserves microclimatic regimes needed by moisture-dependent species. Effective conservation of the corridors is thus critical to the maintenance of ecosystem processes, species richness, and long-term ecological integrity of the sanctuary.

4.4. Integrated Conservation Interventions and Community-Oriented Management Strategies within Chandaka Wildlife Sanctuary

Major conservation interventions for Chandaka Wildlife Sanctuary involve legal protection of key mature forest patches with anti-poaching patrols and legal interventions, and restoration of degraded corridors with native tree plantation and assisted natural regeneration. Control of invasive species is done by mechanical removal and surveillance, and fire management uses community firebreaks, early warning systems, and prescribed burns [24, 25, 26]. Reducing dependence on forest resources through human–wildlife conflict mitigation strategies of compensation and crop-protection, coupled with community participation and encouragement of alternative livelihoods, ensures the long-term conservation of ecosystems and sustainability of biodiversity.

4.5. Integrated Long-Term Conservation Action Framework for Chandaka Wildlife Sanctuary

A prioritized action plan for Chandaka Wildlife Sanctuary sets out actions in short-, medium-, and long-term timeframes to guarantee successful conservation. Short-term (0–2 years) actions comprise a baseline monitoring program via standardized transects, camera traps, and water quality testing; rapid eradication of invasive species in priority areas around core habitats; awareness campaigns by local communities encouraging sustainable resource extraction; and intensified patrolling to combat poaching and immediate threats. Medium-term (2–5 years) strategies emphasize habitat recovery, such as native sapling nurseries, reforestation of essential corridors, and riparian area recovery. Fire protection plans are collaboratively designed with communities, and ecotourism or work programs based on the community (guided trails, handicrafts) are implemented to reward conservation [23, 26]. Livestock grazing control defines reserved zones beyond core forest. Long-term (>5 years) interventions address landscape-level connectivity to minimize forest fragment isolation, development of institutional collaborations with forest departments, NGOs, and universities for adaptive management, and creation of long-term ecological research plots to track climate impacts and successional dynamics, maintaining sustained ecosystem resilience and biodiversity conservation [27, 28].

4.6. Management and Community Participation Framework for Sustainable Conservation in Chandaka Wildlife Sanctuary

Effective management of Chandaka Wildlife Sanctuary involves a mix of biodiversity conservation and local community involvement. A permanent monitoring cell in the forest division will enable standardized monitoring of species, habitats, and threats over time. Co-management with local people, by providing employment opportunities, microfinance for processing of NTFP, and training, can yield real benefits with diminished dependency on forest wealth. Protection of water supplies and riparian cover is essential to species dependent on aquatic environments [27, 29, 30]. Targeted invasive species removal, particularly in regions posing threats to rare or endemic species, with native replanting, will improve habitat quality. School and community environmental education programs will develop awareness and stewardship. The inclusion of climate resilience, including the promotion of habitat heterogeneity and drought-resistant species, provides for long-term ecosystem stability. Nevertheless, the research has several limitations. The temporal extent (single- or two-season surveys) is possibly not adequately capturing phenological or seasonal changes [30, 31] Sampling bias impacts detectability, making occupancy models appropriate future

recommendations. There are gaps in data for aquatic invertebrates and hard-to-detect taxa, and detailed surveys with special methods will be needed to provide complete biodiversity estimations.

Conclusion

Chandaka Wildlife Sanctuary continues to be an important repository of biodiversity in the face of threats from its location close to urban settlements, agricultural land use, and local resource utilization. The sanctuary harbors a variety of habitats mature Sal forests, degraded or mixed forests, grasslands, and riparian zones—that together support variable taxa, from large mammals and birds to reptiles, amphibians, and plants of understory habit. While intact core forest preserves specialist species and high structural diversity, degraded mosaics supply edge habitats that are inhabited by generalist species and add to total species richness. Effective conservation, therefore, calls for a balanced strategy, where strict protection of core forest patches is integrated with restoration of degraded corridors through reforestation, rehabilitation of riparian zones, and control of invasive species. Combining community involvement, via awareness campaigns, alternative livelihoods, and community management, ensures local ownership and alleviates anthropogenic pressures. Combined with adaptive monitoring and long-term research, such approaches can promote ecological integrity, maintain habitat connectivity, and endure the essential ecosystem services like water regulation, carbon storage, and biodiversity maintenance offered by the sanctuary.

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