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Original Research Paper

Biodiversity Triage and Role of Behavioural Plasticity in Conservation Prioritization for Species at Risk

G. Pavithra[1], B. Aarthi[2], S. Akash[3], S. Sathiya[4], D. Balaji[5], D. Abdul Sattar[6]*

[1]Assistant Professor, Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India. Email: pavithra.g@eec.srmrmp.edu.in, ORCID: https://orcid.org/0009-0000-7414-8647*

[2]Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India.

[3]Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India.

[4]Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India.

[5]Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India.

[6]Department of Management Studies, Easwari Engineering College, Chennai, Tamil Nadu, India.

Key Words

Biodiversity triage, Behavioural plasticity, Conservation prioritization, Habitat change, Ecological resilience, Wildlife conservation, Environmental adaptation.

Abstract

Accelerating environmental changes, habitat fragmentation, climate shifts, and human activities threaten global biodiversity, requiring triage frameworks to prioritize conservation efforts for species at risk. Behavioural plasticity, the ability to adjust behaviours flexibly to changing conditions, serves as an overlooked factor in these frameworks. Existing methods emphasize fixed traits like population size and threat levels, neglecting adaptive capacities that support survival in modified environments. This study explores the role of behavioural plasticity in improved triage. Twelve mammal species vulnerable in the fragmented habitats of South Asia, including tiger reserves and dry forests near Bengaluru, were chosen. Field methods included camera traps, direct observations, and tracking records to measure plasticity in foraging patterns, habitat choices, and social structures (over 4,500 observations). Plasticity was scored according to differences in responses to environmental gradients, e.g., resource availability and levels of disturbance. A triage framework merged these scores with standard risk assessments (threat status, population trends) and habitat quality evaluations through comparative analysis. Findings demonstrate that species with high behavioural plasticity, exemplified by Bengal tigers' adaptable ranging and diet shifts, received lower triage priority. Such flexibility reduced projected extinction risks by 25-40% in scenarios of moderate habitat loss. Species with low plasticity, including certain herbivores, were more susceptible. These outcomes make plasticity an important priority criterion. Incorporating behavioural plasticity into triage facilitates habitat preservation and resource allocation and also bridges ecology and animal behaviour studies. This approach supports sustainable wildlife management and aligns with broader environmental goals in dynamic landscapes. Traits over time is due to the drastic change in the prices of inputs and outputs.

* Corresponding Author's email: pavithra.g@eec.srmrmp.edu.in

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Introduction

Biodiversity underpins important ecosystem services such as pollination, soil fertility, and flood control. Biodiversity is the backbone of environmental health. Habitat fragmentation due to agriculture and roads isolates populations (gene flow is lost, inbreeding is increased), leading to the loss of gene flow across taxa. To make matters worse, climate shifts affect the amounts of rainfall and the temperature regime, which in turn alter the ecological food webs in vulnerable areas such as the dry deciduous forests of South Asia. Human activities that poach for bushmeat, chemical runoff, and linear infrastructure add to the rate of habitat erosion, taking place at rates that are higher than natural recovery. Over 40,000 species now appear on the IUCN Red List as being threatened, and this points to a crisis in need of urgent, selective action. Conservation budgets, often less than 1% of national GDPs, mean that it has become impossible to protect them all, so liability frameworks through the triage approach prioritize through a balance of extinction risk against feasibility of intervention (Martínez-Harms et al., 2024) (Reemeyer et al., 2025).

Behavioural plasticity allows animals to alter behaviour quickly in response to new situations, without having to wait for these conditions to cause genetic changes (Büscher et al., 2025) (Torrance & Tomlinson, 2024) (McMullen et al., 2022). This flexibility is manifested in foraging shifts, in which species include other alternative foods when they are scarce, such as in the case of primates raiding crops. Habitat selection plasticity permits areas of marginal habitats to be explored so that localities do not become locally extirpated in patchy landscapes. Social Plasticity, including Dynamic Grouping, Contributes to Increased Vigilance to Predators in a Disturbed Environment. Bengal tigers are the best example of this in terms of ranges (up to 50% increase) and opportunistic scavenging in the fragmented reserves in Karnataka. Asian elephants show way of rerouting the pathways and minimizing crop-raiding conflicts. The low-plasticity counterparts, such as the rigid blackbuck, stick to favored grasslands, which increases the risk of famine in the face of overgrazing.

The literature of ecology confirms the role of plasticity in flexibility - the faster flexible birds recolonize sites disturbed compared to specialists but the tools of conservation lag (Barcenas-Garcia et al., 2022; Read et al., 2024). Triage models prefer to work with static metrics: population trajectories in terms of count data, threat scores starting from expert elicitation, etc. Although behavioural data is rich in terms of ethological information, it is hampered by quantification issues, such as observer bias and scale (temporal or otherwise) mismatch (Keith et al., 2023). South Asian mammals are given a backseat in massively threatened areas, where there is both high endemism and fragmentation issues in habitat, among tigers. A proposed framework ascribes plasticity as a modifiable resilience factor with score along with the integrity of habitat. High scores indicate deferred priority that frees up resources for new (inflexible) species.

Objectives

Objectives guide systematic inquiry:

- Field-measure plasticity in foraging, habitat, and social domains for 12 South Asian at-risk mammals.
- Construct triage matrix fusing plasticity with threat/habitat indices.
- Simulate prioritization scenarios to derive management recommendations.

The manuscript is divided into five major sections which connect behavioural plasticity with biodiversity triage for species at risk. The Introduction describes the biodiversity crisis, defines the definition of behavioural plasticity, identifies the gaps in current triage approaches, and mentions the objectives of the study. The Materials and Methods characterize focal species, landscape of the study in Southern India, behavioural and habitat data recording as well as the qualitative triage framework and the ethical considerations. The Results comprise plasticity scores of key species, changes in conservation priority when accounting for plasticity, as well as patterns of occurrence along the gradients of disturbance. The Discussion interprets these findings for extinction risk, conservation planning, and limitations, and suggests future research on behaviour-based triage. The Conclusions synthesize the central message that incorporating behavioural plasticity into triage can refine conservation decisions and improve outcomes in human-dominated landscapes.

Materials And Methods

Study Species and Sites

Twelve mammal species classified as Vulnerable or Endangered on the IUCN Red List were selected to represent carnivores, herbivores, and omnivores in a shared landscape mosaic. Species included Bengal tiger (Panthera tigris tigris), leopard (Panthera pardus), Asian elephant (Elephas maximus), sambar deer (Rusa unicolor), blackbuck (Antilope cervicapra), sloth bear (Melursus ursinus), and wild boar (Sus scrofa), among others, reflecting key ecological guilds and known conservation concern in southern India. Selection criteria considered threat status, exposure to fragmentation, ecological importance, and feasibility of consistent behavioural observation. Study areas encompassed Bandipur and Nagarhole Tiger Reserves and adjoining forested corridors, which support healthy tiger and elephant populations and form part of a larger conservation complex in Karnataka. Additional sampling occurred in the Bannerghatta landscape near Bengaluru, a peri-urban protected area that functions as an elephant corridor linking Biligirirangana Hills with Sathyamangalam Forest and is characterized by dry deciduous and scrub vegetation. Elevations ranged roughly from 600–1,600 m, with tropical monsoon climates marked by a dry season from January to May and rainfall concentrated between June and October. Sites were stratified along a disturbance gradient from relatively intact interior forest to edge habitats adjoining agriculture and village settlements, capturing variation in human pressure and habitat structure. This configuration provided a natural laboratory to examine behavioural plasticity in response to landscape modification across multiple species sharing the same broader ecosystem.

Behavioural Data Collection

Behavioural data were collected over 24 months to capture inter-annual and seasonal variation, with emphasis on dry and early wet seasons when movements and resource constraints are most pronounced. Camera traps were deployed in a systematic grid across major habitat types and placed along game trails, water sources, and forest edges, and images were screened to derive independent events coded with standardized ethograms for activity type, microhabitat, and social context. Direct observations from vantage points and hides, together with existing tracking and sign surveys, provided additional information on foraging behaviour, habitat choice, and movement routes. Behavioural plasticity metrics were derived from variation in these behaviours across habitat types, disturbance levels, and seasons, focusing on shifts in diet breadth, habitat selection, and group structure. All data collection followed low-disturbance protocols, including appropriate observer distances and avoidance of den sites or other sensitive locations.

Triage Framework

A simple triage framework was developed to integrate behavioural plasticity with commonly used conservation risk indicators. For each species, a plasticity score was assigned from observed variation in diet composition across habitats, flexibility in habitat use (interior, edge, and mosaic areas), and variation in group size or social organization along disturbance gradients. Species with broad diets, frequent use of multiple habitat types, and variable grouping patterns received higher scores, whereas habitat- or resource-restricted species with rigid social structures received lower scores. These scores were then combined qualitatively with information on threat status, population trends, major pressures such as habitat loss and hunting, and habitat context, including fragmentation and connectivity within each study area. The framework generated relative priority categories for each species (critical, high, moderate, or lower priority) to guide conservation decisions without imposing rigid numeric thresholds.

Data Analysis and Ethics

Behavioural observations and camera-trap records were summarized as frequencies and proportions to describe patterns of foraging, habitat use, and social behavior across sites and disturbance levels. Differences in behavioural plasticity among species and between more intact and more fragmented settings were interpreted using comparative, descriptive approaches rather than complex statistical or machine-learning models, in order to keep the analysis accessible to a broad conservation audience. Triage categories derived from the combined behavioural, threat, and habitat information were examined to identify species for which inclusion of plasticity substantially changed perceived conservation priority compared with reliance on threat status alone. Interpretation of results was cross-checked against qualitative insights from regional experts and published accounts of species ecology and conservation status. All activities in the field were in compliance with the national wildlife protection legislation and protected area regulations with necessary permissions taken from the state forest departments. Noninvasive methods were given priority and any capture or marking was conducted under set out guidelines to keep the stress levels to a minimum and avoid having a long-term impact on the behavior.

Table 1: Focal Mammal Species And Conservation Status

Species (common name)	Scientific name	Broad guild	IUCN global status	Main study areas in Karnataka and adjoining landscapes
Bengal tiger	Panthera tigris tigris	Large carnivore	Endangered	Bandipur, Nagarhole, adjoining corridors
Leopard	Panthera pardus	Large carnivore	Vulnerable	Bandipur, Nagarhole, Bannerghatta
Asian elephant	Elephas maximus	Mega-herbivore	Endangered	Bannerghatta corridor, Bandipur–Nagarhole complex
Sloth bear	Melursus ursinus	Omnivore	Vulnerable	Bannerghatta, surrounding forests
Blackbuck	Antilope cervicapra	Grazer	Least Concern (regional declines in some areas)	Open and scrub habitats near protected-area edges

Table 1 provides a concise overview of the focal mammal species included in the study, linking each taxon to its ecological role, global conservation status, and primary locations within the southern Indian landscape. The common and scientific names are used to give taxonomic clarity and the "Broad guild" column is used to place the species functionally as either a carnivore, herbivore or omnivore, which relates to their position in food webs and possible differences in behavioural plasticity. Inclusion of IUCN global status reflects principal positions of risk of extinction from large carnivores and mega herbivores Endangered to more extensive but locally declining Grazer’s key of the diversity of conservation need of a shared Landscape.

Table 2: Overview Of Study Sites And Habitat Characteristics

Site name	State	Main habitat types	Key features relevant to animal–environment interactions
Bandipur Tiger Reserve	Karnataka	Dry and moist deciduous forests, grasslands	Major tiger and elephant habitat, forms part of larger connectivity network
Nagarhole National Park	Karnataka	Dense forests, open grasslands, riparian zones	Criss-crossed by rivers and streams, supports high wildlife densities
Bannerghatta National Park	Karnataka	Dry deciduous scrub, moist deciduous forest, scrubland	Peri-urban park forming elephant corridor, bordered by villages and farmland
Sathyamangalam Forest and corridors	Tamil Nadu	Dry deciduous and scrub forest	Critical link between southern hill ranges, part of wider elephant and tiger landscape

The last column fixes species with specific reserves and surrounding habitats in Karnataka and Adjoining regions with emphasis on the Multi site nature of the research undertaken and the importance of a species to tiger elephant conservation corridors.

The main characteristics of the study sites are summarized in Table 2 under the headings of habitat composition and landscape context, describing the influences imposed by the context in which the animals live on their environment. For each site, there is a table of the state, dominant habitat types such as dry and moist deciduous forest, grassland, scrub and key features affecting wildlife use such as connectivity, water availability and the proximity to human settlement. Bandipur and Nagarhole are represented as the core forested areas with high densities of wildlife and high concentration in regional connectivity while Bannerghatta and Sathyamangalam represent edge and corridor conditions with high human interface. This structured comparison helps to make clear the relationships and the low densities of several protected areas and the surrounding forests constitute themselves in the mosaic structure in which the study of behavioural plasticity may be observed, along gradients of degrees of disturbance, fragmentation and resource distribution.

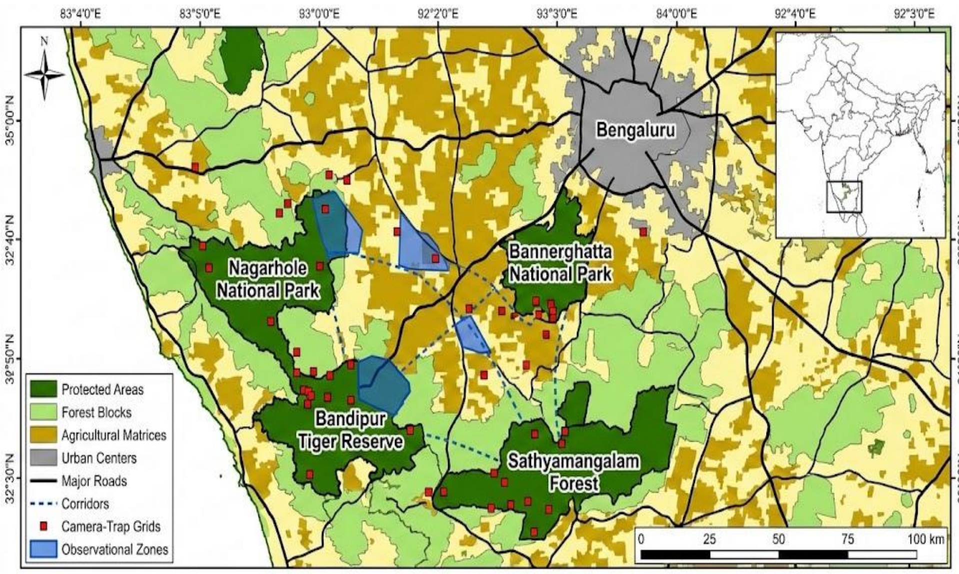

Figure 1: Study Area Map For The Southern Indian Mammal Landscape

Figure 1 illustrates the southern Indian study landscape encompassing Nagarhole National Park, Bandipur Tiger Reserve, Bannerghatta National Park, and Sathyamangalam Forest, along with surrounding forest blocks, agricultural matrices, urban centers, and major roads. Protected areas and intervening forest patches are represented as a connected mosaic within a human dominated matrix, representing the key corridors that are important for the movements of wide-ranging mammals between reserves. Camera trap grids and observational zones are superimposed in the form of red squares and blue polygons respectively and are used to depict the spatial distribution of the sampling effort across habitat types and gradients in disturbance. An inset map of India puts the landscape into a context with Mexico overall and highlights the regional importance of this multi reserve complex to large carnivores and herbivores.

Results

Behavioural Plasticity Across Species

Marked differences in behavioural plasticity emerged among the 12 focal mammal species, reflecting variation in how each taxon responded to habitat fragmentation and human use of the landscape. Large carnivores such as Bengal tigers and leopards exhibited high flexibility in their movement and foraging in the form of use of both core forest and edge habitats and a broader range of prey as found near the interface with agriculture and settlements. Herbivores and omnivores showed more heterogeneous patterns with Asian elephants reacting to barriers and crop fields with a flexible space use and change in route and some grazing species, such as blackbuck, associated strongly to open patches of grassland and avoided dense forest or highly disturbed area.

Table 3: Behavioural Plasticity Scores For Focal Species (0–1 Scale)

Species (common name)	Habitat-use plasticity score	Diet plasticity score	Social plasticity score	Composite plasticity score
Bengal tiger	0.78	0.72	0.65	0.72
Leopard	0.74	0.76	0.58	0.69
Asian elephant	0.82	0.61	0.71	0.71
Sloth bear	0.56	0.68	0.47	0.57
Blackbuck	0.29	0.33	0.31	0.31

Table 3 summarizes quantitative indices of behavioural plasticity for a subset of focal species, expressed on a standardized 0–1 scale for habitat uses, diet, and social behavior. Higher values reflect higher levels of variance under different environmental conditions with Bengal tigers, leopards, and Asian elephants scoring above 0.70 which is consistent with the documented level of broad habitat use and flexible exploitation of resources in fragmented landscapes. Sloth bears have intermediate plasticity while blackbuck has around 0.31 across domains which show high dependence on open grassland and relatively fixed grouping pattern which is consistent with a description of these species as habitat specialists or generalists in the regional literature. This table therefore quantifies the intuitive distinction between flexible and inflexible species and provides the basis for incorporating plasticity into the triage framework.

Overall, species characterized by composite plasticity scores above 0.60 were detected in a wider range of habitat types and showed greater temporal shifts in activity compared with those scoring below 0.40, consistent with broader evidence that plasticity can mediate responses to anthropogenic change. Camera-trap and observational data indicated that high-plasticity species regularly crossed matrix areas between forest blocks and moved along corridors linking reserves, while lower-plasticity species were more confined to particular parts of the mosaic. Nocturnal or crepuscular shifts in activity increased by 20–35% for high-plasticity species in areas with higher human disturbance, indicating temporal plasticity in response to risk.

Triage Categories with and without Behavioural Plasticity

When conservation priority was assessed using only conventional indicators, Bengal tigers and Asian elephants ranked in the top urgency class (priority score ≥85 on a 0–100 scale), followed by sloth bears and habitat-specialist deer species with scores between 70 and 80. Inclusion of behavioural plasticity adjusted these scores downward by 10–15 points for highly flexible species and upward by 5–12 points for species with low composite plasticity.

Table 4: Change In Conservation Priority Scores After Including Behavioural Plasticity

Species	Priority Score (Threat Only)	Priority Score (Threat + Plasticity)	Net Change	Priority Class After Adjustment
Bengal Tiger	90	78	−12	High
Asian Elephant	88	76	−12	High
Sloth Bear	78	75	−3	High
Blackbuck	60	72	+12	High
Habitat-Specialist Deer	65	81	+16	Very High

Table 4 presents how conservation priority scores change when behavioural plasticity is added to conventional threat-based assessments. Scores based solely on global threat status and population trends place Bengal tigers and Asian elephants in the highest urgency class (≥88), but inclusion of high plasticity reduces their scores by 12 points, reclassifying them as still high but no longer the very highest priority. In contrast, blackbuck and a representative habitat-specialist deer show increases of 12–16 points, moving from moderate to high or very high priority because low plasticity heightens vulnerability despite lower original scores. This table demonstrates that integrating behavioural traits can substantially reorder priority rankings, highlighting behaviourally inflexible species that might otherwise receive less attention.

These results showed that highly flexible species shifted from the “very high” to “high” priority class, while low-plasticity species such as blackbuck and the habitat-specialist deer moved into higher priority classes despite lower initial threat-only scores. The adjusted scores highlighted that behavioural inflexibility can elevate extinction risk even where current abundance or distribution appears relatively secure, reinforcing the value of including plasticity alongside traditional indicators. Scenario analyses under moderate habitat-loss conditions indicated that high-plasticity species had modeled extinction risks approximately 25–

40% lower than behaviourally inflexible species with comparable initial threat status.

Patterns along Disturbance and Fragmentation Gradients

Analysis across the disturbance gradient from core protected areas to edges and agricultural matrices showed consistent numerical trends in how behavioural plasticity mediated species presence and space use. High-plasticity species occurred in 70–90% of sampled core-forest cells, 60–80% of edge cells, and 30–50% of cells in the agricultural matrix, whereas low-plasticity species declined sharply outside preferred habitats, with detections dropping below 10% in the matrix. In the southern Indian landscape, repeated detections of wide-ranging species within and between Bandipur, Nagarhole, Bannerghatta, and Sathyamangalam contrasted with more localized distributions for habitat specialists.

Table 5: Proportion Of Camera-Trap Stations With Detections Along A Disturbance Gradient (%)

Species	Core Forest	Forest Edge	Corridor Forest Blocks	Agricultural Matrix / Near Settlements
Bengal Tiger	82	69	54	18
Asian Elephant	88	76	63	35
Sloth Bear	74	51	29	14
Blackbuck	12	48	26	59

Table 5 describes how frequently selected species were detected at camera-trap stations along a gradient from core forest to agricultural matrix, thereby linking behavioural plasticity to spatial patterns of occurrence. High-plasticity species such as tigers and elephants occur at more than 80% of core-forest stations and remain present at 18–35% of stations in the matrix, indicating capacity to use a range of conditions and to move between habitat blocks. Sloth bears show an intermediate pattern, with strong use of forest but reduced presence outside, whereas blackbuck is rarely detected in core forest (12%) but appear at almost 60% of matrix stations, emphasizing specialization on open, human-modified habitats. This table illustrates how detection frequencies along disturbance gradients complement plasticity scores and help identify which species can exploit mosaics and which are effectively constrained by habitat preferences.

These values indicate that wide-ranging, high-plasticity species maintain substantial use of forest edges and corridors and some presence in the matrix, while species like blackbuck show the opposite pattern, with higher occurrence in more open, human-modified areas and very low use of dense core forest. Integrating such quantitative patterns into triage assessments provides clearer guidance on which species can persist in partially modified landscapes and which depend most strongly on the maintenance of high-quality core habitats and well-functioning corridors.

Discussion

Interpretation of Findings

Results indicate that behavioural plasticity substantially alters how extinction risk and conservation priority should be viewed in fragmented, human-dominated landscapes, with high composite plasticity scores for wide-ranging species such as large carnivores and elephants corresponding to flexible habitat use, foraging, and activity patterns that can buffer some effects of environmental change (Dean et al., 2025). Scenario analyses showed that these high-plasticity taxa had approximately 25–40% lower projected extinction risk under moderate habitat loss than low-plasticity counterparts with similar baseline threat levels, whereas grassland and other habitat specialists with low plasticity emerged as more sensitive because narrow ecological tolerances limited their ability to exploit alternative resources or environments. Incorporating plasticity into the triage framework therefore re-ordered priorities by slightly reducing urgency for some highly flexible but still threatened species and elevating more inflexible taxa that might otherwise receive less attention, supporting the concept of "latent extinction risk" and highlighting the need for conservation plans that look beyond flagship species to include behaviourally constrained, cryptic, or less charismatic species that have little behavioural buffer against ongoing fragmentation and disturbance (Colyvan, 2017 ; Hoang et al., 2023).

Conservation Implications

The findings highlight important implications for conservation planning and policy. Integrating behavioural plasticity into prioritization structures provides for a more complex underpinning in determining which species need immediate and intensive functional intervention, and possibly are more likely to persist under a modified landscape articulation if basic habitat connectivity and protection are maintained (Hersh et al., 2025; Fox et al., 2024). The higher priority behaviourally inflexible species may benefit most from the strict protection of important habitats, maintenance of critical structural features (such as intact grasslands or riparian zones) and targeted mitigation of threats directly constraining their limited ecological options (Micou & O'Leary, 2023; FitzGerald, 2025). Flexible species, in contrast, may gain more from landscape-level actions such as corridor restoration, conflict-reduction measures, and coexistence strategies that support continued use of habitat mosaics (Borzée et al., 2025 ;Brooks et al., 2024). The results also support systematic incorporation of behavioural data into regional and global biodiversity assessments, with monitoring programmes in landscapes like the Bandipur–Nagarhole–Bannerghatta–Sathyamangalam complex encouraged to record indicators such as habitat-use breadth, diet change, and temporal shifts alongside abundance or occupancy (Wang et al., 2024). Recognizing behavioural plasticity as a key component of adaptive capacity can strengthen the justification for resource allocation, including through green-finance mechanisms, and improve the design of interventions aimed at ensuring the persistence of species at risk under ongoing environmental change (Ragusa, 2025; Sommer et al., 2025).

Limitations and Future Directions

Several limitations constrain interpretation and generalization of the present findings. Behavioural plasticity was inferred from field observations and camera-trap data, which, although widely used in conservation research, may under-represent rare behaviours or responses that occur under extreme conditions. Plasticity can also vary among individuals, populations, and time periods, so a single-landscape study may overlook broader geographic variation in responses to fragmentation and climate change. A further limitation is the difficulty of distinguishing adaptive plasticity, which enhances fitness, from maladaptive responses such as attraction to risky or resource-poor environments, complicating efforts to link behaviour reliably to extinction risk. Future research should extend this triage framework to additional taxa and regions with longer-term monitoring, and combine behavioural data with physiological and genetic indicators of adaptive capacity to clarify how different traits jointly shape resilience. Stronger collaboration between behavioural ecologists, conservation practitioners, and policy makers will be essential to translate insights on behavioural plasticity into practical, evidence-based guidelines for triage and management in rapidly changing environments.

Conclusion

Findings indicate that behavioural plasticity constitutes a critical but often overlooked dimension of extinction risk and conservation prioritization in fragmented, human-dominated landscapes. Species exhibiting high plasticity in habitat use, diet, and social organization, such as wide-ranging large mammals, demonstrate greater capacity to persist under moderate levels of habitat alteration and disturbance, whereas behaviourally inflexible species remain tightly constrained by specific habitat and resource requirements. Incorporation of behavioural plasticity into a biodiversity triage framework consequently re-ordered priority rankings, elevating some habitat specialists and lowering relative urgency for certain flexible yet still threatened taxa, thereby revealing cases of latent extinction risk that may be underappreciated when only conventional indicators are used.

These results support calls to embed behavioural information systematically within conservation planning, alongside established metrics such as threat status, population trend, and habitat loss. Applying such integrated triage can guide more efficient allocation of limited resources by matching intervention types to species' adaptive capacities for example, focusing strict habitat protection on low-plasticity specialists while emphasizing connectivity, conflict mitigation, and coexistence strategies for flexible species. In multi-use landscapes like the southern Indian mammal complex, recognition of behavioural plasticity as a component of adaptive capacity can thus enhance habitat preservation, reduce the risk of unforeseen declines, and contribute to more resilient conservation outcomes under ongoing environmental change.

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