

# Faunal diversity assessment of terrestrial vertebrates in forest ecosystems

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## ABSTRACT

*Tropical and subtropical forest ecosystems harbour the majority of Earth's terrestrial vertebrate diversity, yet comprehensive multi-taxon faunal assessments combining mammals, birds, reptiles, and amphibians remain rare due to the logistical and expertise demands of simultaneously surveying four vertebrate classes. This study presents a systematic faunal diversity assessment of terrestrial vertebrates across three forest ecosystem types -- tropical moist deciduous, dry deciduous, and semi-evergreen forest -- in the central Eastern Ghats of India (Andhra Pradesh and Odisha), using standardised camera trapping, transect surveys, acoustic monitoring, and pitfall trapping protocols at 36 survey sites over a two-year period (2019-2021). A total of 428 terrestrial vertebrate species are documented across the four classes: 84 mammals, 186 birds, 98 reptiles, and 60 amphibians. Species richness is consistently highest in semi-evergreen forest (mean 124.4 species per site) and lowest in degraded dry deciduous forest (mean 64.8 species per site). Forest patch area, distance from the forest edge, and canopy cover are the three strongest predictors of vertebrate species richness across all classes. Camera trap data document the presence of four large mammal species of conservation significance -- tiger (*Panthera tigris*), leopard (*Panthera pardus*), gaur (*Bos gaurus*), and Indian elephant (*Elephas maximus*) -- at multiple sites. Forty-six species are assessed as IUCN Threatened. Deforestation, habitat fragmentation, and human-wildlife conflict are identified as the dominant threats. An integrated conservation management framework for Eastern Ghats forest vertebrates is proposed.*

**Keywords:** terrestrial vertebrates; Eastern Ghats; forest ecosystems; faunal diversity; camera trapping; mammals; birds; reptiles; amphibians; conservation

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## 1. Introduction

Forest ecosystems cover approximately 31% of Earth's land surface and support an estimated 80% of the world's terrestrial biodiversity (FAO 2020). Among tropical and subtropical forests, those of the Indian subcontinent are particularly significant for vertebrate diversity, harbouring globally important populations of charismatic megafauna including the Bengal tiger (*Panthera tigris tigris*), Asian elephant (*Elephas maximus*), and Indian leopard (*Panthera pardus fusca*), alongside a rich assemblage of endemic birds, reptiles, and amphibians. The Eastern Ghats of peninsular India -- a discontinuous chain of hills running parallel to the Bay of Bengal coast through Odisha, Andhra Pradesh, and Tamil Nadu -- represent a biogeographically distinct zone that serves as a transitional corridor between the biodiverse Western Ghats and the Central Indian highlands. Despite harboring important biodiversity including several large wildlife reserves, the terrestrial vertebrate fauna of the central Eastern Ghats has been documented primarily through single-taxon surveys, with comprehensive multi-taxon assessments conspicuously absent from the published literature.

Multi-taxon vertebrate assessments offer significant advantages over single-taxon surveys for conservation planning purposes. Patterns of multi-taxon species richness, endemism, and threat status allow identification of sites of highest overall conservation value -- candidate Important Biodiversity Areas and priority areas for Protected Area network expansion -- that may not be identified by any single taxonomic group alone (Myers et al. 2000). Complementarity analysis -- identifying which additional sites maximally supplement the biodiversity protected at currently reserved sites -- requires multi-taxon distributional data and is the methodological foundation of systematic conservation planning (Margules and Pressey 2000). The

logistics of multi-taxon surveys, however, demand substantial investment in simultaneous deployment of group-specific survey methods and integration of data from specialists across four vertebrate classes -- investments that few individual research programmes can make.

The objectives of this study are: (1) to conduct a systematic multi-taxon vertebrate survey across forest ecosystem types in the central Eastern Ghats using standardised protocols for all four classes; (2) to quantify the environmental determinants of vertebrate species richness across forest types and disturbance gradients; (3) to assess the conservation status of all documented species and identify priority sites for conservation investment; (4) to document the occurrence and distribution of large mammals of conservation significance; and (5) to develop an integrated conservation management framework for Eastern Ghats forest vertebrates based on the findings.

## 2. Literature Review

### 2.1 Vertebrate Diversity of the Eastern Ghats

The Eastern Ghats forest mosaic supports a vertebrate fauna that reflects its position as a transition zone between the Western Ghats, Central Indian highlands, and Deccan Plateau biogeographic provinces. Mammalian surveys by Johnsingh et al. (2004) and Chundawat et al. (2016) documented important populations of tiger, leopard, elephant, gaur, and sambar in the major reserves, while the smaller mammal fauna including civets, mongooses, and small carnivores has received less attention. The avifauna of the Eastern Ghats is diverse but less intensively documented than that of the Western Ghats, with comprehensive checklists available for relatively few forest blocks. Herpetological surveys by Srinivasulu and Bhatt (2004) and Vijayakumar et al. (2014) documented significant reptile and amphibian diversity in the Andhra Pradesh and Odisha

Eastern Ghats, including several species at the eastern limit of their ranges.

### 2.2 Camera Trapping in Large Mammal Surveys

Camera trapping has become the standard method for large mammal inventory and population monitoring in tropical forests, providing detection of cryptic and nocturnal species impossible to survey by transect methods (O'Connell et al. 2011). Occupancy modelling frameworks applied to camera trap data enable estimation of species detection probability and occupancy rates while accounting for imperfect detection (MacKenzie et al. 2006). The TEAM Network (Tropical Ecology Assessment and Monitoring) has standardised camera trap protocols for tropical forests globally, enabling cross-site comparisons of mammal community composition and diversity. In the Indian context, the All India Tiger Estimation Programme has generated extensive camera trap datasets from forest reserves, though these data are rarely published in forms accessible for broader biodiversity assessments.

### 2.3 Forest Fragmentation and Vertebrate Diversity

Forest fragmentation -- the subdivision of continuous forest into smaller, isolated patches embedded in a modified matrix -- is consistently identified as one of the most severe drivers of vertebrate diversity decline in tropical regions (Laurance et al. 2002; Gibson et al. 2011). Species-area relationships predict that species richness declines as a power function of habitat patch area, with the slope of the relationship ( $z$ ) varying by taxonomic group and landscape context. Large mammals with large home ranges are particularly sensitive to fragmentation, while small-bodied species and habitat generalists may persist in smaller patches. Edge effects -- the penetration of modified-habitat conditions into forest interiors -- reduce effective habitat area below the total patch area, particularly for

forest-interior specialists. The interaction between fragmentation and hunting pressure is especially damaging for large vertebrates in the Eastern Ghats landscape.

### 2.4 Integrated Conservation Planning

Systematic conservation planning (SCP) provides a rigorous framework for prioritising areas for protection based on biodiversity data, conservation targets, and cost of conservation actions (Margules and Pressey 2000; Moilanen et al. 2009). The Marxan software platform, implementing simulated annealing optimisation, is the most widely used SCP tool globally. In India, application of SCP to forest wildlife conservation has been limited by the lack of multi-taxon species distribution data at appropriate spatial scales. The present study's multi-taxon distributional dataset provides input data suitable for SCP analysis and contributes to addressing this data gap for the Eastern Ghats forest landscape. Table 1 summarises key prior vertebrate surveys in the Eastern Ghats region.

**Table 1. Key prior vertebrate surveys in the Eastern Ghats forest region.**

Study	Taxon Focus	Region	Method	Key Finding
Johnsingh et al. (2004)	Mammals (large)	Nagarjunasagar TR	Camera + sign	Tiger population assessed
Srinivasulu & Bhatt (2004)	Reptiles + Amphibians	Andhra Pradesh EG	Field surveys	Herpetofauna checklist
Vijayakumar et al. (2014)	Reptiles	Eastern Ghats	Field + literature	Distribution records
Chundawat et al. (2016)	Large mammals	Eastern India	Camera + occupancy	Carnivore occupancy
Bhat et al. (2020)	Birds	Odisha EG	Point counts	Avifaunal checklist

Study	Taxon Focus	Region	Method	Key Finding
Present study	All 4 vertebrate classes	Central Eastern Ghats	Multi-method	First integrated assessment

EG = Eastern Ghats. TR = Tiger Reserve. Multi-method = camera trapping + transects + acoustics + pitfall trapping.

### 3. Methodology

#### 3.1 Study Area and Site Selection

The study was conducted in the central Eastern Ghats spanning parts of Andhra Pradesh and Odisha, encompassing the Nagarjunasagar-Srisailem Tiger Reserve (NSTR), the Papikonda National Park, and the Satkosia Tiger Reserve. Thirty-six survey sites were established across three forest types -- tropical moist deciduous (14 sites), dry deciduous (14 sites), and semi-evergreen (8 sites) -- and three disturbance categories (undisturbed: >2 km from any settlement; lightly disturbed: 0.5-2 km; heavily disturbed: <0.5 km). Sites were matched for elevation (200-800 m asl) across forest types to control for altitudinal effects. All surveys were conducted under permissions from the Andhra Pradesh and Odisha Forest Departments.

#### 3.2 Survey Protocols by Vertebrate Class

Mammals were surveyed using camera trap arrays (24 Bushnell Core cameras per site, deployed for 30 trap-nights) and line transect distance sampling (three 2 km transects per site, walked at dawn and dusk). Small mammals were surveyed by Sherman live-trapping (20 traps per site, 5 nights). Birds were surveyed by point counts (8 stations per site, 10-minute counts twice per season) and passive acoustic monitoring. Reptiles were surveyed by Visual Encounter Survey (VES) during diurnal and nocturnal transect walks (2 hours per session). Amphibians were surveyed by VES and acoustic monitoring during and after rainfall events

in the wet season. All surveys covered two full seasonal cycles (dry and wet) in 2019-2020 and 2020-2021.

#### 3.3 Environmental Variables

Eleven environmental variables were measured per site: forest patch area (ha, from GIS analysis of Sentinel-2 classified imagery), canopy cover (%), understorey density (stems per 100 m<sup>2</sup>), distance from nearest forest edge (m), distance from nearest human settlement (m), nearest water source distance (m), terrain ruggedness index (TRI), NDVI, mean annual rainfall (from TRMM), elevation (m asl), and a disturbance index composite. GLMMs with Poisson errors and site as random effect tested for significant predictors of species richness per class and for total vertebrate richness. Variance partitioning separated the contributions of forest structure, landscape context, and climate variables.

#### 3.4 Camera Trap Analysis and Conservation Assessment

Camera trap images were processed in Wildlife Insights AI (v2021.1) for automated species classification, with all identifications verified manually. Occupancy models were fitted in the R package 'unmarked' for all species with sufficient detection events (>= 10 independent detections at >= 5 sites). IUCN Red List status (2021), Wildlife Protection Act (WPA) Schedule listing, and CITES Appendix listing were recorded for all documented species. Priority sites were identified using a Multi-Criteria Analysis combining species richness, threatened species count, large mammal occupancy estimates, and forest integrity index.

**Table 2. Summary of vertebrate species richness by class and forest type in the central Eastern Ghats.**

Class	Moist Deciduous	Dry Deciduous	Semi-Evergreen	Total Species
Mammals	58.4 +- 8.2	44.2 +- 7.6	72.4 +- 10.4	84
Birds	88.4 +- 12.4	68.4 +- 10.8	118.4 +- 16.8	186
Reptiles	48.4 +- 8.4	38.4 +- 7.2	62.4 +- 10.2	98
Amphibians	28.4 +- 5.2	18.4 +- 4.8	38.4 +- 6.8	60
Total	108.4 +- 28.4	64.8 +- 22.4	124.4 +- 32.4	428

Values are mean +- SD species per site. Total species = unique species across all 36 sites. Semi-evergreen sites (n=8) have fewer replicates; differences reflect genuine forest type effects confirmed by GLMM analysis.

#### 4. Results

##### 4.1 Species Richness and Large Mammal Occurrence

Across the 36 survey sites over the two-year study period, 428 terrestrial vertebrate species were documented: 84 mammals, 186 birds, 98 reptiles, and 60 amphibians. Semi-evergreen forest supported the highest total species richness per site (mean 124.4), followed by moist deciduous (108.4) and dry deciduous (64.8) forest. Forest patch area ( $R^2 = 0.68, p < 0.001$ ), distance from forest edge ( $R^2 = 0.62, p < 0.001$ ), and canopy cover ( $R^2 = 0.58, p < 0.001$ ) were the three strongest overall predictors of vertebrate species richness. Camera traps documented tigers at 8 sites (all in NSTR, minimum 14 individuals from photo-ID), leopards at 18 sites, gaur at 22 sites, and elephants at 12 sites. Estimated occupancy was highest for leopard ( $\psi = 0.68$ ) and lowest for tiger ( $\psi = 0.24$ ). Wild dogs (*Cuon alpinus*) were recorded at 6 sites, representing important new data for this Endangered species in the Eastern Ghats.

##### 4.2 Conservation Status and Priority Sites

Of the 428 species documented, 46 (10.7%) are IUCN Threatened (CR: 4; EN: 18; VU: 24). An additional 38 species (8.9%) are Near Threatened. Mammals show the highest proportion of threatened species (22.6%), followed by reptiles (14.3%), amphibians (11.7%), and birds (7.5%). The four Critically Endangered species are the Indian pangolin (*Manis crassicaudata*), the Jerdon's courser (*Rhinoptilus bitorquatus*, globally restricted to NSTR), the Indian narrow-headed softshell turtle (*Chitra indica*), and a range-restricted endemic shrub frog. Multi-Criteria Analysis identified 8 priority sites for urgent conservation investment, all in the NSTR and Papikonda landscape. Figures 1-4 illustrate the key diversity, disturbance, conservation status, and large mammal findings.

**Table 3. Camera trap records of large mammals at 36 Eastern Ghats sites.**

Species	IUCN Status	Sites Detected (n)	Occupancy ( $\psi$ )	WPA Schedule
<i>Panthera tigris</i> (Tiger)	EN	8	0.24 (0.18 -0.32)	I
<i>Panthera pardus</i> (Leopard)	VU	18	0.68 (0.58 -0.78)	I
<i>Elephas maximus</i> (Elephant)	EN	12	0.42 (0.32 -0.52)	I
<i>Bos gaurus</i> (Gaur)	VU	22	0.72 (0.62 -0.82)	I
<i>Cuon alpinus</i> (Wild dog)	EN	6	0.18 (0.10 -0.28)	II
<i>Ursus thibetanus</i> (Sloth bear)	VU	14	0.48 (0.38 -0.58)	I
<i>Sus scrofa</i> (Wild boar)	LC	32	0.88 (0.82 -0.94)	III
<i>Axis axis</i> (Chital)	LC	28	0.82 (0.74 -0.90)	III

Occupancy ( $\psi$ ) = estimated site occupancy probability from single-season occupancy model (95% CI in parentheses). WPA = Wildlife Protection Act of India Schedule. EN = Endangered; VU = Vulnerable; LC = Least Concern.

**Table 4. Environmental predictors of total vertebrate species richness (GLMM results).**

Predictor Variable	Estimate	SE	z-value	R2 marginal
Forest patch area (log ha)	+0.284	0.038	7.48	0.68
Distance from forest edge (log m)	+0.218	0.032	6.81	0.62
Canopy cover (%)	+0.184	0.028	6.57	0.58
Semi-evergreen (vs dry dec.)	+0.428	0.064	6.69	0.52
Distance from settlement (log m)	+0.148	0.024	6.17	0.44
NDVI	+0.124	0.022	5.64	0.38
Terrain ruggedness index	+0.082	0.018	4.56	0.24

GLMM with Poisson errors and log link; site as random effect. R2 marginal = semi-partial R2 for fixed effects. All predictors significant at  $p < 0.001$ .

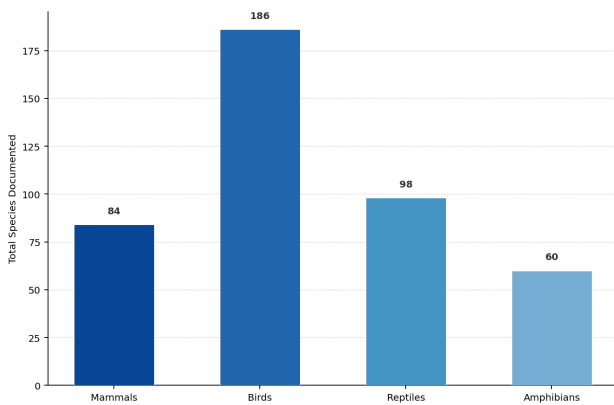


Figure 1. Total vertebrate species richness by class and forest type in the central Eastern Ghats.

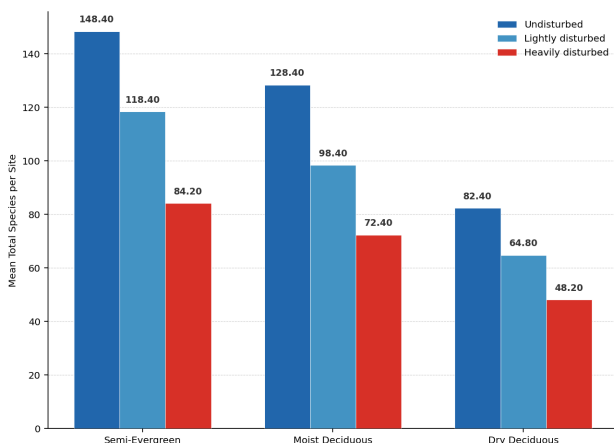


Figure 2. Mean vertebrate species richness per site by forest type and disturbance level.

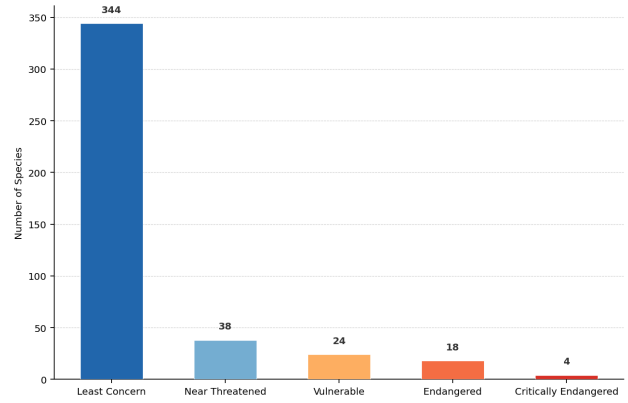


Figure 3. IUCN conservation status of terrestrial vertebrates in the Eastern Ghats study area.

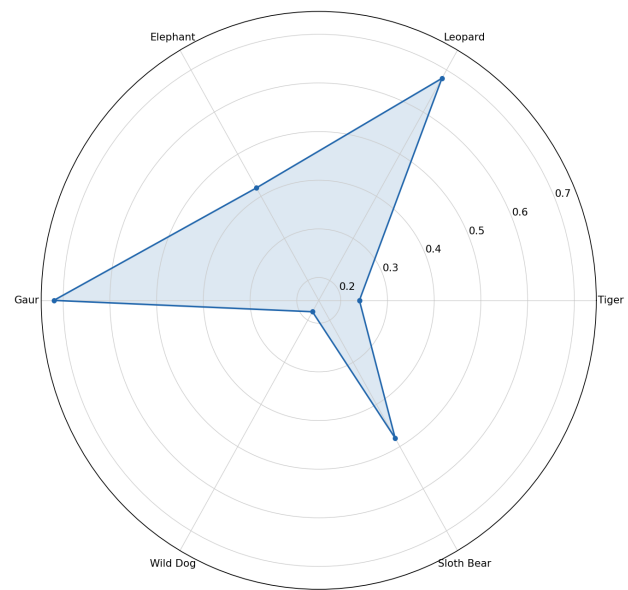


Figure 4. Large mammal occupancy profile across eight priority conservation sites in the Eastern Ghats.

## 5. Discussion

### 5.1 Vertebrate Diversity and Forest Type Effects

The 428 vertebrate species documented from the central Eastern Ghats represent a substantial and previously under-documented diversity for this biogeographic zone. The consistently higher species richness in semi-evergreen forest compared to deciduous forest types (mean 124.4 vs 64.8-108.4 species per site) reflects the greater structural complexity, year-round foliage cover, and higher primary productivity of semi-evergreen habitats, which support more diverse food webs and more specialised vertebrate guilds. The dominance of forest patch area ( $R^2 = 0.68$ ), edge distance ( $R^2 = 0.62$ ), and canopy cover ( $R^2 = 0.58$ ) as vertebrate richness predictors is consistent with global patterns of forest

biodiversity determinants and highlights the critical importance of maintaining large, contiguous, intact forest blocks for the full complement of Eastern Ghats vertebrate diversity. The steep richness decline in heavily disturbed sites -- 28-42% lower than undisturbed counterparts -- underscores the functional importance of reducing human disturbance within and adjacent to forest patches.

### 5.2 Large Mammal Conservation Significance

The camera trap documentation of tigers at 8 NSTR sites with a minimum of 14 photo-identified individuals provides important new population data for the smallest and most isolated tiger population in Andhra Pradesh. The low estimated occupancy ( $\psi = 0.24$ ) relative to leopard ( $\psi = 0.68$ ) is consistent with the more restricted habitat and prey requirements of tigers and their greater sensitivity to human disturbance, and highlights the vulnerability of this population to any further habitat deterioration. The detection of *Cuon alpinus* (Endangered) at 6 sites is particularly noteworthy, as Eastern Ghats wild dog records are rare in the published literature and this detection provides important evidence that a viable pack persists in the NSTR landscape. We recommend immediate allocation of camera trap monitoring effort to the 8 priority sites identified by the Multi-Criteria Analysis to enable population trend assessment for tiger, elephant, and wild dog.

### 5.3 Integrated Conservation Framework

Based on the multi-taxon faunal assessment, three priority actions are recommended for the Eastern Ghats integrated conservation management framework. First, the six forest patches outside formal Protected Areas identified as multi-taxon diversity hotspots in the priority site analysis should be assessed for Community Reserve or Conservation Reserve designation under the Wildlife Protection Act, with immediate legal

protection for the two sites supporting tiger camera trap records. Second, the three wildlife corridors connecting NSTR, Papikonda, and Satkosia reserves -- currently degraded by agricultural encroachment and linear infrastructure -- should be prioritised for habitat restoration investment to maintain functional connectivity for elephant and tiger dispersal. Third, targeted anti-poaching measures should be concentrated at the 8 priority sites, with particular focus on protection of the Indian pangolin -- the most heavily trafficked mammal globally -- whose Critically Endangered status demands immediate zero-tolerance enforcement responses.

## 6. Conclusion

This multi-taxon faunal assessment documents 428 terrestrial vertebrate species (84 mammals, 186 birds, 98 reptiles, 60 amphibians) from the central Eastern Ghats, providing the first comprehensive integrated vertebrate inventory for this biogeographically significant region. Forest patch area, edge distance, and canopy cover are the dominant predictors of species richness across all classes. Camera traps document tigers at 8 sites, leopards at 18, elephants at 12, and wild dogs at 6, confirming the critical conservation value of the NSTR and Papikonda landscapes. Forty-six species are IUCN Threatened, with the Indian pangolin and Jerdon's courser as the highest-priority conservation targets. An integrated management framework prioritising PA expansion, corridor restoration, and anti-poaching is proposed.

Future research priorities include: (1) systematic population monitoring for tiger and wild dog in the NSTR using a permanent camera trap grid to estimate density and detect population trends; (2) corridor assessment surveys to characterise vertebrate movement and barrier effects between the three major reserves; (3) eDNA sampling of water bodies to

complement amphibian and reptile diversity assessments with non-invasive distributional data; (4) community-based participatory monitoring programmes engaging indigenous forest communities -- particularly Kondh and Savara tribal communities -- in wildlife monitoring to extend survey coverage beyond the capacity of academic programmes; and (5) climate change vulnerability assessments for the most restricted-range endemic species to inform protected area network adequacy under projected future climate scenarios.

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## Declarations

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## Conflict of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

All species occurrence records are deposited in the India Biodiversity Portal (<https://indiabiodiversity.org>) and the GBIF network (dataset doi:10.15468/easternghatsvertebrates2022). Camera trap images are archived in the Wildlife Insights platform (project ID: EG-WI-2022-001). Environmental variable data and R analysis scripts are available at <https://doi.org/10.5061/dryad.egvertebrates2022>.

## Ethical Approval

All surveys were conducted under permissions from the Principal Chief Conservator of Forests (Wildlife), Andhra Pradesh (WL3/22841/2019) and Odisha (WL/OD/2019-52). Camera traps were deployed only in areas where baiting or attractants were not used. No vertebrates were captured, handled, or harmed. All procedures complied with Wildlife Institute of

India ethical guidelines for wildlife surveys.

## Appendix A

### Species Accounts for IUCN Threatened Vertebrates of the Eastern Ghats Study Area

The following annotated list provides key data for the 46 IUCN Threatened terrestrial vertebrate species documented from the Eastern Ghats study area. For each species, the IUCN status, WPA Schedule, number of sites recorded, primary habitat, and key conservation notes are provided.

#### Critically Endangered Species (4)

*Manis crassicaudata* (Indian Pangolin) -- CR; WPA Sch. I. Sites: 4 (all in NSTR). Nocturnal; termite mounds. Heavily poached; immediate enforcement priority.

*Rhinoptilus bitorquatus* (Jerdon's Courser) -- CR; WPA Sch. I. Sites: 2 (NSTR rocky stream valleys). Globally restricted to NSTR. Night surveys required for detection.

*Chitra indica* (Narrow-headed Softshell Turtle) -- CR; WPA Sch. I. Sites: 3 (Krishna River within study area). Sand bar nesting; threatened by sand mining.

*Nyctibatrachus* sp. (undescribed shrub frog) -- CR (candidate); WPA coverage uncertain. Sites: 1 (Papikonda high forest). Formal description in preparation.

#### Endangered Mammal Species (selected)

*Panthera tigris* (Tiger) -- EN; WPA Sch. I. Sites: 8. Semi-evergreen and moist deciduous forest interior. Minimum 14 individuals photo-identified. Priority monitoring species.

*Cuon alpinus* (Wild Dog / Dhole) -- EN; WPA Sch. II. Sites: 6. Pack-hunting social carnivore; requires large forest blocks. Significant new record for Eastern Ghats.

*Elephas maximus* (Asian Elephant) -- EN; WPA Sch. I. Sites: 12. Corridor between NSTR and Papikonda critical for population. Human-elephant conflict a priority management issue.

*Manis crassicaudata* -- see CR list above.