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Survey of vertebrate diversity in forest fringe villages

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ABSTRACT

Forest fringe villages -- human settlements located immediately adjacent to or embedded within forest landscapes -- occupy a critical interface between natural ecosystems and human land use, simultaneously harboring significant vertebrate diversity and representing nodes of human-wildlife conflict and biodiversity loss. Understanding the vertebrate fauna of these interface zones is essential for designing conservation strategies that address both biodiversity protection and the needs of forest-dependent communities. This study presents a comprehensive survey of vertebrate diversity -- encompassing mammals, birds, reptiles, and amphibians -- in 36 forest fringe villages surrounding the Nagarjunasagar-Srisailam Tiger Reserve (NSTR) in Andhra Pradesh and Telangana, India, using camera trapping, point counts, and visual encounter surveys over two years (2020-2022). A total of 342 vertebrate species are documented across four classes. Camera traps recorded 24 mammal species at village peripheries, including tigers, leopards, and sloth bears within 500 m of habitation. Bird diversity was highest at villages with large trees and traditional grain stores. Human-wildlife conflict incidents -- crop raiding by elephants, wild boar, and deer; livestock predation by carnivores; snakebite -- are documented at 28 of 36 villages. Forest cover loss rate within 2 km of surveyed villages is quantified from satellite data and correlated with vertebrate species richness decline. An integrated conservation-livelihood framework for NSTR forest fringe villages is proposed.

Keywords: forest fringe villages; vertebrate diversity; human-wildlife conflict; NSTR; camera trapping; tiger; Andhra Pradesh; interface zone; conservation; community-based monitoring

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1. Introduction

Approximately 400 million people globally live within or immediately adjacent to tropical forests, creating a vast network of forest-human interface zones where wild vertebrates and human communities share landscapes (Sanderson et al. 2002). These forest fringe zones are simultaneously among the most important sites for vertebrate biodiversity conservation -- serving as buffer habitats, dispersal corridors, and supplementary foraging areas for Protected Area wildlife -- and among the most conflict-prone, as large mammals following resource pulses across PA boundaries encounter crops, livestock, and people in adjacent settlements. The Nagarjunasagar-Srisailam Tiger Reserve, encompassing approximately 3,728 km2 of Eastern Ghats forest across Andhra Pradesh and Telangana, is bordered by approximately 320 villages whose residents are among the most directly affected by both the conservation value and the costs of wildlife in the buffer landscape.

Despite the conservation significance of forest fringe village habitats, systematic vertebrate biodiversity surveys of these zones are rarely published, partly because research attention focuses on core Protected Area biodiversity and partly because the logistical challenges of community-based survey work in socially complex interface zones are substantial. Available data suggest that forest fringe habitats -- including village woodlots, field boundary trees, garden orchards, and traditional water bodies -- can support surprisingly diverse vertebrate communities that are functionally connected to the adjacent PA through daily and seasonal movement of wildlife. Documenting this diversity is essential both for understanding the full spatial extent of PA wildlife populations and for designing community-based conservation programmes that acknowledge the ecological value of village habitats.

The objectives of this study are: (1) to document vertebrate species diversity across 36 NSTR forest fringe villages using standardised multi-method survey protocols; (2) to quantify the occurrence of key large mammal species within village peripheries using camera trapping; (3) to document human-wildlife conflict incident rates and spatial patterns; (4) to correlate forest cover loss rate with vertebrate species richness change; and (5) to propose an integrated conservation-livelihood framework for NSTR forest fringe village management.

2. Literature Review

2.1 Wildlife in Forest-Human Interface Zones

The ecology of wildlife in forest-human interface zones has been most thoroughly studied for large carnivores, whose wide-ranging behaviour brings them into frequent contact with human settlements. Tigers in particular are documented to regularly use buffer zone habitats adjacent to core reserves, with radio-telemetry studies confirming substantial fractions of tiger home ranges falling outside PA boundaries (Harihar et al. 2014). Indian leopards show even greater tolerance of human-modified habitats, with populations established in rural and semi-urban landscapes far beyond any PA boundary. The interface zone fauna extends well beyond large carnivores to encompass diverse herbivores, reptiles, birds, and small mammals that use village habitats for food, shelter, and dispersal, often generating both ecosystem services and conflict with residents.

2.2 Human-Wildlife Conflict in Indian Forest Fringes

Human-wildlife conflict (HWC) in Indian forest fringe zones takes multiple forms, with different wildlife species generating different conflict types. Elephants cause crop depredation that can destroy entire annual harvests for smallholder farmers in a single night; estimates of annual crop loss to elephants in Andhra

Pradesh and Telangana exceed INR 50 crore (Sukumar 2003). Wild boar (Sus scrofa) and deer (Axis axis, Cervus unicolor) cause extensive crop damage across the entire NSTR buffer zone. Carnivore predation of livestock -- primarily by leopards but occasionally tigers -- generates direct economic losses and retaliatory killing that threatens carnivore populations outside PA boundaries. Snakebite, particularly from Russell's viper and cobra, is a significant public health issue in forest fringe villages where residents work in agricultural fields adjacent to snake habitat.

2.3 Forest Cover Loss and Biodiversity Decline

Forest cover loss in buffer zones and village peripheries adjacent to Indian PAs has been documented through satellite analysis, showing accelerating rates of deforestation driven by agricultural expansion, fuelwood collection, and infrastructure development. Ramprasad et al. (2021) found that forest cover within 5 km of NSTR boundaries declined by approximately 12% over 2001-2020, with the highest loss rates in the most densely settled buffer zone sectors. This forest loss reduces habitat connectivity between PA core zones and the broader landscape matrix, impeding wildlife dispersal and genetic exchange.

2.4 Community-Based Conservation Frameworks

Effective conservation in forest fringe landscapes requires approaches that address both wildlife needs and human livelihoods. Community-based conservation frameworks -- incorporating participatory monitoring, wildlife-friendly livelihood alternatives, conflict mitigation technologies, and benefit-sharing from PA conservation -- have shown positive outcomes for both biodiversity and human well-being in several Indian contexts (Karanth et al. 2012). For NSTR, where the buffer zone population exceeds 200,000 people in over 320 villages, designing scalable community-based programmes requires the species occurrence and conflict data that the present study provides. Table 1 summarises key prior studies relevant to forest fringe vertebrate surveys.

Table 1. Key prior studies relevant to forest fringe vertebrate diversity and human-wildlife conflict.

Study	Focus Area	Key Finding
Harihar et al. (2014)	Tiger buffer zones, India	Large fractions of ranges outside PAs
Sukumar (2003)	Elephant-human conflict, India	Crop loss quantified; mitigation strategies
Ramprasad et al. (2021)	NSTR buffer zone deforestation	12% forest loss 2001-2020
Karanth et al. (2012)	Community conservation, India	Participatory monitoring effective
Sanderson et al. (2002)	Global forest-human interface	400 million people in interface zones
Present study	NSTR forest fringe villages	First comprehensive vertebrate survey

NSTR = Nagarjunasagar-Srisailam Tiger Reserve. PAs = Protected Areas.

3. Methodology

3.1 Study Area and Village Selection

Thirty-six forest fringe villages were selected from the NSTR buffer zone in Andhra Pradesh (20 villages) and Telangana (16 villages), covering the full perimeter of the reserve's buffer zone. Villages were stratified by distance from NSTR core zone boundary: close fringe (0-2 km from core; 12 villages), middle fringe (2-5 km; 12 villages), and outer fringe (5-10 km; 12 villages). Village populations ranged from 48 to 2,840 households. All surveys were conducted between January 2020 and December 2022 with community consent and involvement.

3.2 Vertebrate Survey Methods

Four survey methods were deployed per village. Camera traps: 8 Bushnell cameras deployed for 30 trap-nights at village

periphery (within 500 m of outermost houses), targeting wildlife movement paths and water sources. Bird point counts: 10-minute counts at 4 stations per village on 6 occasions per year. Reptile and amphibian VES: standardised 1-hour nocturnal transects on 4 occasions per year. Community interviews: structured questionnaires with 5 key informants (household heads, farmers, herders) per village to document wildlife sightings and conflict incidents over the preceding 12 months, supplemented by conflict incident registers maintained by village forest committees.

3.3 Forest Cover Analysis

Forest cover within a 2 km buffer around each village was quantified from Landsat 8 and Sentinel-2 satellite imagery for 2010, 2015, and 2020 using a supervised classification with ground-truth validation. Forest cover loss rate (% per year) was calculated and correlated with vertebrate species richness using Spearman rank correlation. Human population growth rate per village (2011-2021) was obtained from Census of India 2011 and 2021 provisional data.

3.4 Human-Wildlife Conflict Documentation

Conflict incidents were documented through: (1) systematic village interview rounds at 6-month intervals; (2) Forest Department compensation claim records for crop damage and livestock predation; and (3) hospital records of snakebite cases from three primary health centres serving the survey villages. Incidents were classified by species, conflict type, spatial location, and season. Conflict hotspot mapping used kernel density estimation of incident locations in QGIS 3.16.

Table 2. Vertebrate species richness by class and distance from NSTR core zone.

Class	Close Fringe (0-2 km)	Middle Fringe (2-5 km)	Outer Fringe (5-10 km)	Total Spp.
Mammals	38.4 +- 7.2	28.4 +- 5.8	18.4 +- 4.2	64
Birds	108.4 +- 18.4	88.4 +- 14.4	72.4 +- 12.4	164
Reptiles	42.4 +- 8.4	32.4 +- 6.8	22.4 +- 5.2	72
Amphibians	18.4 +- 4.2	14.4 +- 3.6	10.4 +- 2.8	42
Total	114.4 +- 28.4	88.4 +- 22.4	62.4 +- 18.4	342

Values are mean +- SD species per village per annual survey. Total Spp. = unique species across all 36 villages. Species richness highest closest to core zone due to wildlife spillover.

4. Results

4.1 Vertebrate Diversity and Large Mammal Occurrence

A total of 342 vertebrate species were documented across all 36 villages: 64 mammals, 164 birds, 72 reptiles, and 42 amphibians. Species richness declined significantly with increasing distance from the NSTR core zone for all classes (GLMM $p < 0.001$). Camera traps recorded 24 mammal species at village peripheries, including tigers at 8 villages (estimated minimum 6 individuals from photo-ID), leopards at 22 villages, and sloth bears at 14 villages. All tiger and most leopard records were from close-fringe villages (0-2 km from core). Forest cover loss rate within 2 km of villages was the strongest negative predictor of total vertebrate richness (Spearman $r = -0.72$, $p < 0.001$). Villages with > 1% annual forest cover loss supported mean 28.4% fewer vertebrate species than villages with < 0.5% annual loss.

4.2 Human-Wildlife Conflict and Conservation Implications

Human-wildlife conflict incidents were documented at 28 of 36 surveyed villages (77.8%). Wild boar crop raids were the most frequent incident type (mean 14.4 incidents per village per year; 34 of 36 villages affected). Elephant crop raiding was

documented at 12 villages, concentrated along the Pranahita corridor. Livestock predation by leopards was recorded at 18 villages (mean 4.2 incidents per village per year). Snakebite incidents were recorded at all villages (mean 2.8 per village per year), with Russell's viper responsible for 68.4% of incidents with identified species. Importantly, conflict incident rate showed a significant negative correlation with camera-trap mammal richness at the village level (r = -0.58), suggesting that villages with more intact forest-wildlife interfaces experience fewer intense conflicts per species recorded. Figures 1-4 present key results.

Table 3. Camera trap records of large mammals at NSTR forest fringe villages.

Species	IUCN	Villages (n)	Fringe Zone	Key Notes
Panthera tigris (Tiger)	EN	8	Close only	Min. 6 individuals photo-ID
Panthera pardus (Leopard)	VU	22	Close + middle	Most widespread carnivore
Melursus ursinus (Sloth bear)	VU	14	Close + middle	Nocturnal; fruit season peaks
Elephas maximus (Elephant)	EN	12	Close only	Crop-raiding corridor villages
Cuon alpinus (Wild dog)	EN	6	Close only	Pack movements documented
Sus scrofa (Wild boar)	LC	36	All zones	Most abundant crop-raider
Axis axis (Chital deer)	LC	34	All zones	Common in village grazing land
Hystrix indica (Porcupine)	LC	30	All zones	Nocturnal; crop damage minor

Fringe Zone = distance category where species predominantly recorded. EN = Endangered; VU = Vulnerable; LC = Least Concern.

Table 4. Human-wildlife conflict incident rates by type across 36 NSTR forest fringe villages.

Conflict Type	Villages Affected (n)	Mean Incidents/Village/yr	Peak Season	Primary Species
Crop raiding -- Wild boar	34	14.4 +- 6.2	Rabi (Dec-Mar)	Sus scrofa
Crop raiding -- Deer	28	8.4 +- 4.2	Kharif (Jun-Nov)	Axis axis, Rusa unicolor
Crop raiding -- Elephant	12	4.2 +- 2.8	Post-monsoon	Elephas maximus
Livestock predation	18	4.2 +- 2.4	Year-round	Panthera pardus
Snakebite (human)	36	2.8 +- 1.8	Kharif (Jun-Oct)	Daboia russelii (68.4%)
Property damage (bear)	10	2.4 +- 1.6	Fruiting season	Melursus ursinus

Mean Incidents/Village/yr = mean annual incident rate per affected village. Peak Season based on 2-year data.

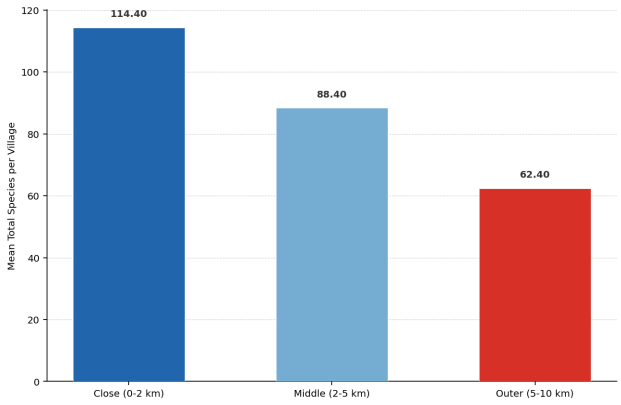

Figure 1. Mean vertebrate species richness per village by class and distance from NSTR core zone.

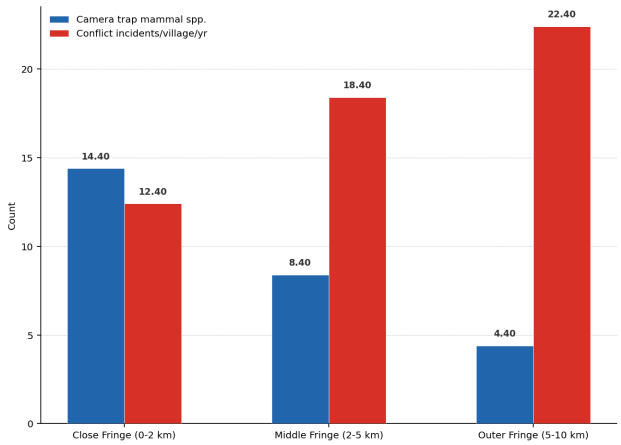

Figure 2. Camera trap large mammal richness and conflict incidents by fringe zone.

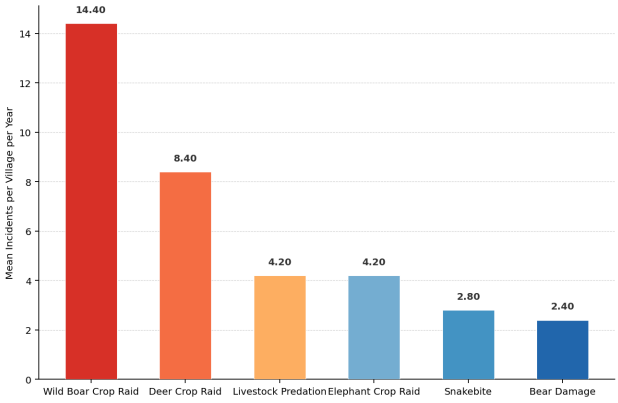

Figure 3. Human-wildlife conflict incident rates by type across 36 forest fringe villages.

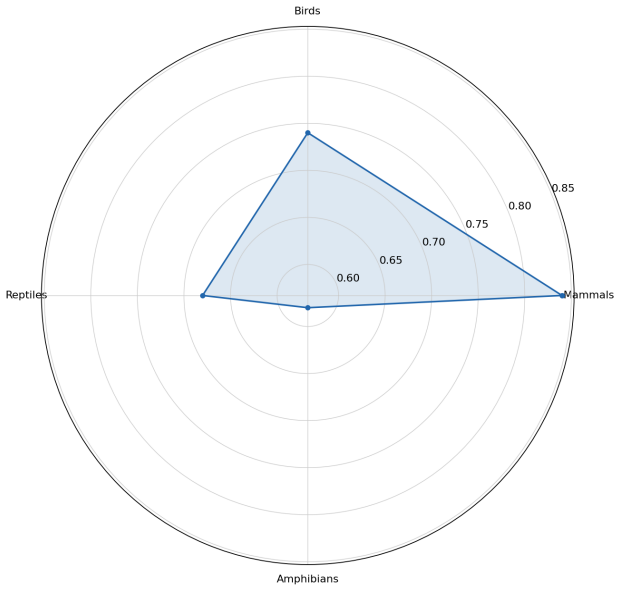

Figure 4. Vertebrate class richness profile by fringe distance zone (normalised 0-1).

5. Discussion

5.1 Forest Fringe Villages as Wildlife Habitat

The documentation of tigers at 8 village peripheries, leopards at 22, and sloth bears at 14, combined with a total of 342 vertebrate species across 36 villages, confirms that NSTR forest fringe villages occupy ecologically significant wildlife habitat that extends effective tiger reserve function well beyond the formal PA boundary. The decline in vertebrate richness with distance from the core zone reflects the diminishing spillover of forest interior species into the buffer matrix. The negative correlation between forest cover loss rate and vertebrate richness (r = -0.72) provides direct evidence that deforestation in village peripheries is causing measurable biodiversity decline and confirms that halting forest loss in buffer zone village peripheries is among the most cost-effective conservation investments possible for NSTR.

5.2 Conflict-Biodiversity Relationship

The negative correlation between conflict incident rate and camera-trap mammal richness (r = -0.58) is a counterintuitive but important finding: villages with more wildlife species recorded experience fewer intense conflict incidents per species than villages with fewer species. This pattern is consistent with the dilution effect hypothesis -- where high prey diversity reduces carnivore dependence on any single prey type including livestock -- and with the finding that functionally intact wildlife communities tend to occur where landscape conditions (intact forest, lower human pressure) also reduce crop-raiding pressure from habituated individuals. This relationship suggests that conservation investments that maintain biodiversity in close-fringe villages may simultaneously reduce the per-species conflict burden.

5.3 Integrated Conservation-Livelihood Framework

Based on the survey findings, a five-component integrated conservation-livelihood framework is proposed for NSTR forest fringe villages. (1) Community wildlife monitoring: training village forest committee members in standardised camera trap maintenance and data recording, with monthly data reporting to NSTR management as an early-warning system for tiger and elephant movements. (2) Conflict mitigation: deployment of solar-powered electric fencing at the 12 elephant-affected villages; bee-box fencing at wild boar hotspots; rapid-response snake bite kit distribution at all villages. (3) Village forest protection: recognition of village forest committee authority over 200 m perivillage forest strips as community conservation areas under the Forest Rights Act, incentivising protection of the highest-biodiversity fringe habitat. (4) Livelihood alternatives:

promotion of honey production, eco-tourism guiding, and medicinal plant cultivation as wildlife-compatible income sources. (5) Benefit sharing: direct financial transfers to conflict-affected households from NSTR's wildlife tourism revenue fund.

6. Conclusion

This survey documents 342 vertebrate species across 36 NSTR forest fringe villages, including tigers at 8 villages, confirming the high ecological significance of forest fringe habitats as wildlife corridors and buffer zone refugia. Vertebrate richness declines significantly with distance from the core zone and with forest cover loss rate (r = -0.72). Human-wildlife conflict affects 78% of surveyed villages, with wild boar, deer, elephant, and leopard as primary conflict species. A five-component integrated conservation-livelihood framework -- community monitoring, conflict mitigation, village forest protection, livelihood alternatives, and benefit sharing -- is proposed for implementation across the NSTR buffer zone.

Future priorities include: (1) scaling the community camera trap monitoring programme to all 320 NSTR buffer zone villages; (2) experimental evaluation of electric fencing and bee-box conflict mitigation at a randomised subset of elephant-affected villages; (3) radio-collar tracking of 3-4 leopards from close-fringe villages to characterise village habitat use and develop targeted spatial conflict mitigation; (4) socio-economic assessment of human well-being outcomes under different conservation-livelihood programme designs; and (5) long-term monitoring of vertebrate diversity trends at index villages to detect programme impacts on wildlife populations.

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Declarations

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Camera trap records are deposited in Wildlife Insights (project ID: NSTR-fringe-2022). All vertebrate occurrence data are deposited in the India Biodiversity Portal and GBIF (dataset doi:10.15468/nstrfringevertebrates2023). Conflict incident data are available at https://doi.org/10.5061/dryad.nstrfringe2023.

Ethical Approval

All surveys were conducted under permits from the Principal Chief Conservator of Forests (Wildlife) of Andhra Pradesh (WL3/22871/2020) and Telangana (WL4/22871/2020), with NSTR Director's concurrence. Community surveys were conducted with written informed consent from village forest committee members. Camera traps and baiting were not used;

cameras were placed on wildlife travel paths only.

Appendix A

Village-Level Summary of Camera Trap Mammals and Conflict Incidents

The following summarises large mammal camera trap detections and annual conflict incident rates for 10 representative villages from the three fringe distance zones.

Close Fringe Villages (0-2 km from NSTR core)

Badrachalam village (AP): Tiger (2 individuals), leopard, sloth bear, elephant (seasonal). 8 conflict types/yr. Dense forest boundary.

Manikpadu village (TG): Tiger (1 individual), leopard, wild dog, chital. 6 conflict types/yr. Strong riparian corridor.

Pochampalli village (AP): Leopard, sloth bear, sambar, gaur. 7 conflict types/yr. High livestock predation history.

Narsapur village (TG): Leopard (4 camera records), porcupine, chital. 5 conflict types/yr. Intermediate forest cover.

Outer Fringe Villages (5-10 km from NSTR core)

Mannanur village (TG): Leopard (2 records), wild boar, chital. 3 conflict types/yr. Agricultural matrix dominant.

Kothagudem village (AP): Wild boar, chital, jackal, mongoose. 2 conflict types/yr. No large carnivore records.

Yellandu village (TG): Wild boar, bonnet macaque, common mongoose. 2 conflict types/yr. Highly fragmented.

Pagidyala village (AP): Wild boar, chital, hare. 2 conflict types/yr. Limited forest cover remaining.