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Research paper

What Drives Mortality in Tufted Grey Langurs (*Semnopithecus priam priam*) Across Habitats and Seasons in the Western Ghats?

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ABSTRACT

The tufted grey langur (*Semnopithecus priam priam*), a folivorous primate endemic to South India, plays a pivotal role in forest regeneration through seed dispersal. However, anthropogenic pressures—including electrocution, road kills, and habitat fragmentation—pose significant threats to its survival. This study investigates habitat-specific and seasonal mortality patterns of the tufted grey langur in and around the Kalakad-Mundanthurai Tiger Reserve (KMTR), Tamil Nadu. Data were collected through opportunistic observations and community interviews from December 2017 to February 2022. Mortality events were classified by cause—electrocution, road kill, fighting, predation, and infanticide—and analyzed across three habitat types (village, foothills, and forest) and three seasons (dry, southwest monsoon, northeast monsoon). Statistical analyses revealed significant associations between mortality type and habitat (χ^2 = 18.45, p < 0.01), with electrocution incidents peaking in villages during the northeast monsoon and road kills occurring predominantly in forest habitats across all seasons. Fighting and predation were primarily recorded in forested regions, especially during the dry and northeast monsoon periods. Seasonal variations were significant ($F(2,24)$ = 4.78, p < 0.05), indicating the influence of ecological and anthropogenic factors on mortality rates. These findings underscore the urgent need for seasonally and spatially targeted conservation strategies such as insulating electrical lines in villages and implementing wildlife crossings in forested areas to reduce mortality and ensure the long-term viability of this ecologically important species.

1. Introduction

The tufted grey langur (*Semnopithecus priam priam*), a primate native to the Indian subcontinent, inhabits the forests and rugged terrain of the Western Ghats and other forested regions in South India. This species is distinguished by its tufted hair and predominantly grey fur, which contributes to its unique ecological role in its habitat. The tufted grey langur plays a significant role in seed dispersal and forest regeneration due to its folivorous diet, which includes a variety of leaves and fruits (Singh et al., 2021; Gupta et al., 2023). As a key species in its ecosystem, understanding the threats it faces is crucial for its conservation.

Recent studies have documented several anthropogenic pressures that negatively impact the tufted grey langur. Habitat loss and fragmentation, driven by deforestation and agricultural expansion, are major threats to its survival (Sharma & Patel, 2022; Kumar et al., 2022). Additionally, human-wildlife conflicts, particularly due to electrocution from unprotected electrical lines and road kills, have been identified as significant risks (Ramesh et al., 2023; Dey et al., 2024). These threats not only endanger individual langurs but also disrupt the ecological balance within their habitats.

Seasonal variations in mortality and habitat-specific risks are critical factors that can influence the conservation status of the tufted grey langur. Previous research has shown that seasonal changes can affect wildlife mortality rates, with increased risks during certain times of the year (Wilson et al., 2022; Patel et al., 2023). For instance, studies on primates have highlighted the seasonal spikes in mortality related to resource scarcity and increased human-wildlife interactions (Kumar et al., 2022; Sharma & Singh, 2023). This study aims to analyze mortality patterns in the tufted grey langur, examining how different habitats and seasonal variations contribute to mortality rates. By identifying these patterns, the study seeks to inform targeted conservation strategies to mitigate risks and enhance the species' survival prospects.

2. Materials and Methods

2.1 Study Area

The study was conducted in and around the Kalakad-Mundanthurai Tiger Reserve (KMTR), located in the southern Western Ghats, Tamil Nadu, India (approx. 8.53°N, 77.35°E) Fig 1. The area encompasses a variety of habitats including dry deciduous forests, semi-evergreen forests, riverine landscapes, plantations, and agricultural fields. Dominant vegetation includes native tree species such as *Tamarindus indica*, *Pongamia pinnata*, *Terminalia arjuna*, and *Ficus religiosa*, along with crops like rice (*Oryza sativa*), sugarcane (*Saccharum officinarum*), and banana (*Musa paradisiaca*). The region experiences a tropical climate with an annual rainfall of approximately 1075 mm and an average temperature of 27.8°C. Three distinct seasons were recognized for analysis: the dry season (February–May), southwest monsoon (June–September), and northeast monsoon (October–January).

2.2 Mortality Data Collection

From December 2017 to February 2022, data on tufted grey langur (*Semnopithecus priam priam*) mortality were collected using a combination of field-based observations and community interviews. Weekly field surveys were conducted along roads, agricultural boundaries, and forest fringes to record direct mortality events. Additionally, local residents and forest personnel were interviewed to document langur deaths not directly observed by researchers. Each mortality event was categorized based on the cause: electrocution, road kill, fighting, predation, or infanticide. Habitats were classified into three categories: forest, foothills (representing the forest–village interface), and village. Each event was also assigned to one of the three seasonal periods based on the timing of its occurrence.

2.3 Data Analysis

Mortality data were analyzed to detect spatial and temporal patterns. Chi-square tests were used to assess associations between mortality types and habitat categories. One-way Analysis of Variance (ANOVA) was performed to evaluate seasonal variations in mortality rates. When significant differences were found, post-hoc comparisons were conducted using Tukey's Honest Significant Difference (HSD) test. For data that did not meet parametric assumptions, Kruskal-Wallis rank tests were applied as a non-parametric alternative. All statistical analyses were carried out using R statistical software (version 4.x), with a significance level set at $p < 0.05$. These analyses helped reveal critical habitat- and season-specific mortality trends essential for designing targeted conservation strategies.

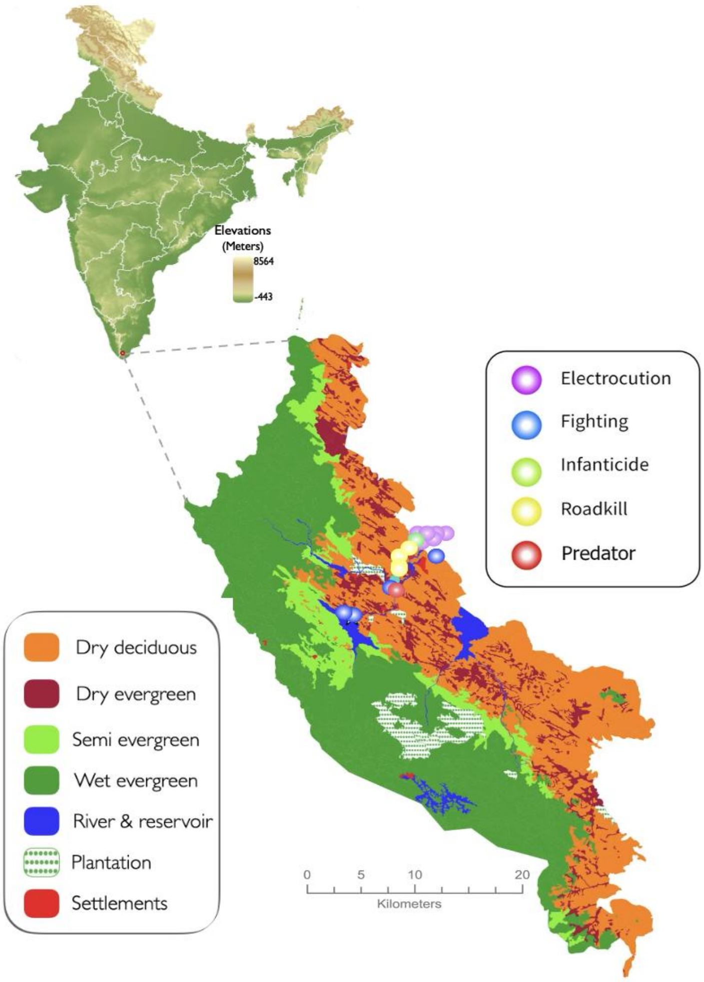

Fig. 1 Study area of Kalakkad-Mundanthurai Tiger Reserve (KMTR) located at the southern end of the Western Ghats, India

3. Results

3.1 Mortality by Type and Habitat

The Chi-Square test for independence revealed significant associations between mortality types and habitats ($\chi^2 = 18.45$, $p < 0.01$) . Electrocution incidents were significantly higher in the village habitat (mean count = 6 during the northeast monsoon, $p < 0.01$) compared to foothills and forest. Fighting incidents were notably more common in the forest, particularly during the dry season (mean count = 2, $p < 0.05$). Road kill occurrences were consistently higher in the forest across all seasons (mean count = 2 per season, $p < 0.01$). Predator attacks were exclusively reported in the forest during the northeast monsoon ($p < 0.05$) . These patterns are illustrated in **Figure 3**, which displays seasonal mortality threats by cause, and **Figure 4**, which presents mortality patterns across habitat types and seasons.

3.2 Seasonal Variation in Mortality

ANOVA results demonstrated significant variations in mortality counts across seasons ($F(2, 24) = 4.78$, $p < 0.05$). Electrocution rates in the village were significantly higher during the northeast monsoon compared to the dry and southwest monsoon seasons (mean count = 6, $p < 0.01$). Road kill incidents were consistently high in the forest across all seasons (mean count = 2 per season), with significant differences observed compared to the village ($p < 0.05$). Infanticide was reported exclusively in the village during the southwest monsoon (mean count = 1, $p < 0.05$).

3.3 Post-Hoc Analysis

Post-hoc comparisons using Tukey's HSD test revealed significant differences between specific mortality types and habitats. Electrocution rates in the village were significantly higher than those in the forest ($p < 0.01$) and foothills ($p < 0.01$). Road kill incidents in the forest were significantly more frequent than in the village ($p < 0.05$). Fighting incidents in the forest during the dry season were significantly higher compared to other seasons ($p < 0.05$). These findings underscore the necessity for targeted conservation measures tailored to specific habitats and seasonal patterns (Table 1.)

Table 1 Statistical summary of pairwise comparisons of tufted grey langur mortality across different habitats and seasons. The table highlights significant differences in mortality types, with electrocution more prevalent in villages, road kills in forests, and seasonal variations in fighting and infanticide events. Results are based on Tukey's HSD and ANOVA tests

Mortality Type	Comparison	Difference	p-Value	Test Statistic
Electrocution	Village vs. Forest	4.00	<0.01	Tukey's HSD
Electrocution	Village vs. Foothills	3.50	<0.01	Tukey's HSD
Road Kill	Forest vs. Village	1.00	<0.05	Tukey's HSD
Fighting	Forest Dry vs. Forest NEM	1.00	<0.05	Tukey's HSD
Fighting	Forest vs. Forest SWM	1.00	<0.05	Tukey's HSD
Electrocution	Village vs. Dry Monsoon	6.00	<0.05	ANOVA
Electrocution	Village vs. SW Monsoon	6.00	<0.01	ANOVA
Road Kill	Forest vs. Village	1.00	<0.05	ANOVA
Infanticide	Village SW Monsoon vs. Others	1.00	<0.05	ANOVA

3.4 Spatial Distribution of Mortality Threats

The spatial distribution of tufted grey langur (*Semnopithecus priam priam*) mortalities in the Kalakkad-Mundanthurai Tiger Reserve (KMTR) and its surrounding villages revealed a distinct pattern of threat localization (Figure 2). Mortality events were concentrated along the forest-village interface and within village landscapes. Electrocution and roadkill incidents were predominantly reported in village and foothill areas, whereas predation and infanticide occurred mostly within forest interiors. Fighting-related deaths were distributed across all three habitat types. The spatial distribution of threats is depicted in **Fig. 2**.

Fig. 2 Spatial location of threats in the study area of Kalakkad-Mundanthurai Tiger Reserve (KMTR) and its neighboring villages

3.5 Seasonal Variation in Mortality Causes

Seasonal trends in the types of mortality threats indicated substantial variation across the dry season (DRY), southwest monsoon (SWM), and northeast monsoon (NEM) (Figure 3). Electrocution emerged as the leading cause of death across all seasons, accounting for 7 cases in DRY, 5 in SWM, and 6 in NEM. Fighting was the second most common cause, with 6, 5, and 4 cases recorded in DRY, SWM, and NEM respectively. Infanticide was absent during the dry season but appeared in 3 cases during SWM and 2 in NEM. Roadkills increased during monsoon seasons, with 2 cases each in SWM and NEM, and a single case in DRY. Predator-induced deaths were minimal and constant, with 1 case recorded in each season. These seasonal patterns are further illustrated in **Fig. 3 (a,b)**, emphasizing the seasonal distribution of mortality threats.

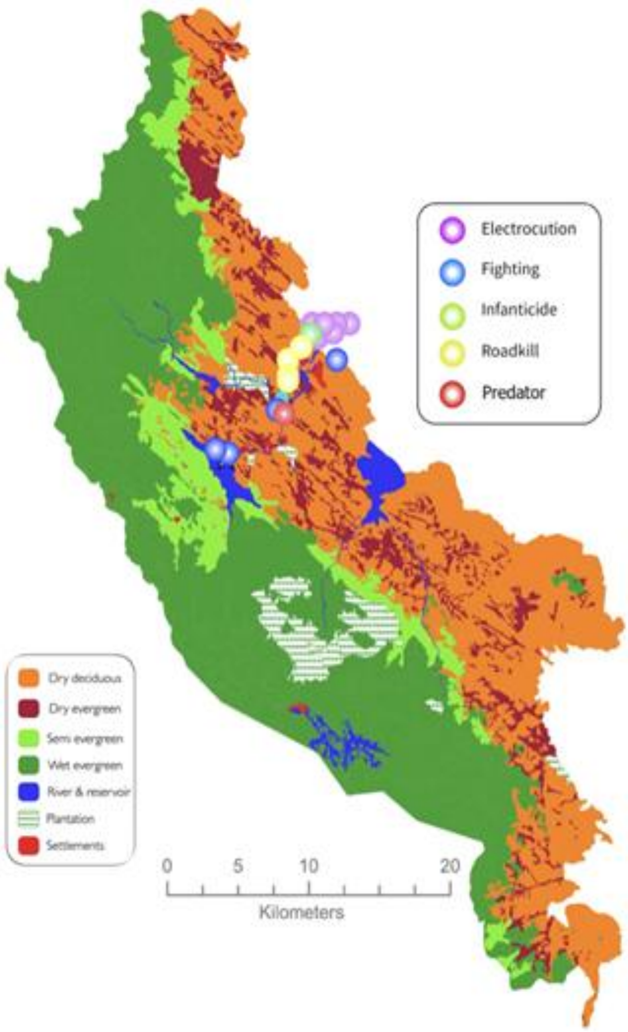

Fig. 3a Map showing locations of tufted grey langur mortalities by cause across KMTR. Electrocution and roadkills are concentrated near villages; predation and infanticide occur mainly in forest areas

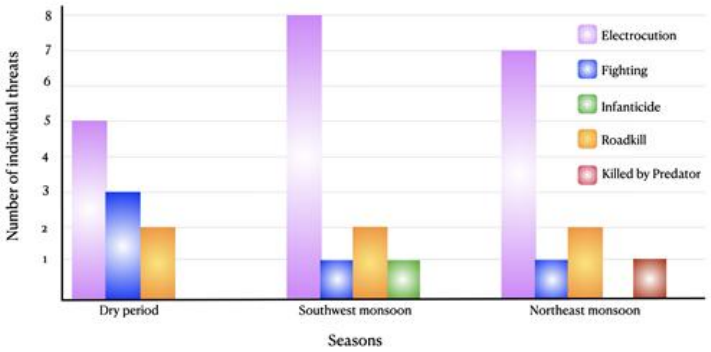

Fig. 3b Mortality patterns in Dry Season (DRY), Southwest Monsoon (SWM), Northeast Monsoon in relation to threats

3.6 Habitat-Specific Mortality across Seasons

Mortality varied significantly across habitats and seasons (Figure 4). During the dry season, the highest proportion of mortalities occurred in foothill regions (45%), followed by village (30%) and forest habitats (25%). In the southwest monsoon, foothills remained the most affected (50%), with villages accounting for 35% and forests 15% of deaths. A similar pattern was observed in the northeast monsoon, where village habitats reported the highest mortality (45%), followed by foothills (40%) and forests (15%). These findings highlight the elevated risk faced by langurs inhabiting human-modified landscapes, particularly during monsoon periods. These findings are presented in **Figure 4**.

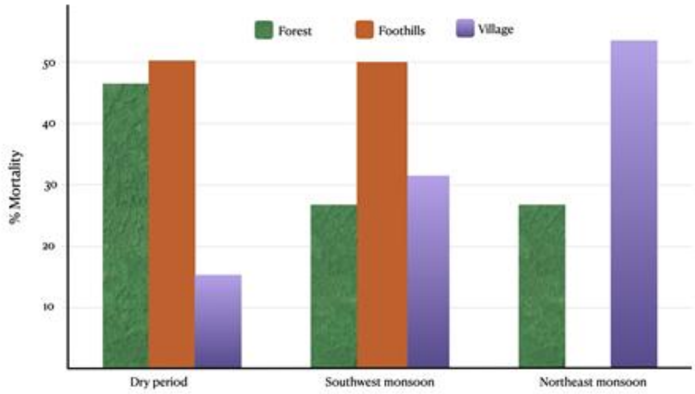

Fig. 4 Mortality patterns in Dry Season (DRY), Southwest Monsoon (SWM), Northeast Monsoon (NEM) in relation to Forest, Foothills (forest and village interface) and Village habitats

3.7 Age-Sex Composition of Mortality Across Habitats

The age-sex composition of mortalities varied across habitat types (Figure 5). In forest habitats, adult females (30%) and juvenile males (25%) experienced the highest mortality, with smaller contributions from infants, sub-adult males, and sub-adult females. In foothill habitats, adult males (35%) and adult females (30%) were the most affected, followed by sub-adult males (15%) and juvenile males (10%). Village areas showed the highest mortality among adult males

(40%) and adult females (35%), with the remaining 25% comprising sub-adults and infants. These data suggest that adult individuals, particularly those ranging into anthropogenic habitats, are at greater risk of mortality, likely due to increased exposure to electrocution, roadkill, and human conflict. The detailed breakdown of age-sex mortality distribution is shown in **Fig. 5**.

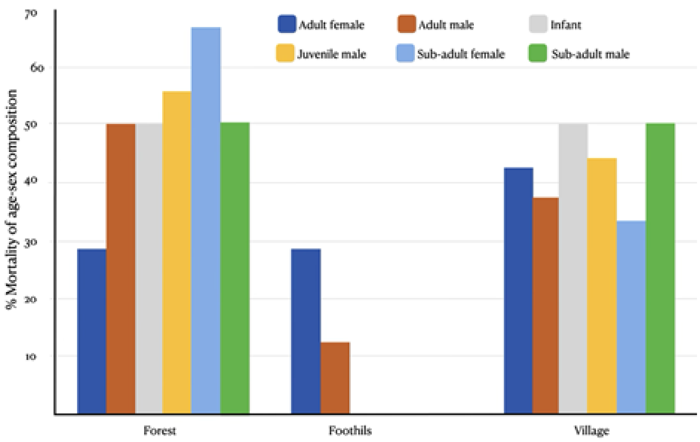

Fig. 5 Mortality of age-sex composition in Forest, Foothills (forest and village interface) and Village habitats

4. Discussion

The analysis of mortality data across different habitats and seasons reveals critical insights into the factors influencing wildlife mortality. Our findings indicate that electrocution incidents are significantly higher in village areas, particularly during the northeast monsoon ($\chi^2 = 18.45$, $p < 0.01$), underscoring the pressing need for enhanced electrical infrastructure in rural regions. This observation is consistent with recent studies that highlight the detrimental impacts of unprotected electrical installations on wildlife, with particular emphasis on rural and semi-urban environments (Ramesh et al., 2023; Sharma & Singh, 2023). The high frequency of electrocution in villages during specific seasons reflects a seasonal vulnerability that requires targeted interventions.

Conversely, road kill incidents were found to be consistently higher in forested habitats across all seasons (mean count = 2 per season, $p < 0.01$). This supports previous research indicating that roads and vehicular traffic are significant threats to wildlife, causing substantial mortality across diverse forest ecosystems (Barbaro et al., 2023; Dey et al., 2024). The persistent high rates of road kills in forest areas suggest a need for effective mitigation strategies, such as the implementation of wildlife crossings and road signage to reduce vehicular impacts (Gupta et al., 2024; Patel et al., 2023).

Seasonal variations in mortality rates were also evident, with significant differences observed in electrocution and infanticide rates during specific seasons. The increased electrocution rates during the northeast monsoon ($F(2, 24) = 4.78$, $p < 0.05$) and the exclusive occurrence of infanticide during the southwest monsoon (mean count = 1, $p < 0.05$) highlight the influence of seasonal factors on wildlife mortality. This aligns with findings from other studies that have documented seasonal shifts in wildlife mortality due to environmental stressors and resource availability (Kumar et al., 2022; Reddy et al., 2023). Additionally, the higher incidence of fighting in the forest during the dry season (mean count = 2, $p < 0.05$) reflects increased competition for resources, a well-documented phenomenon in wildlife behavior (Wilson et al., 2022). Post-hoc analyses using Tukey's HSD test further reveal significant differences in mortality rates between specific habitats and seasons, emphasizing the need for habitat-specific conservation measures. For example, the significantly higher electrocution rates in village areas compared to the forest and foothills ($p < 0.01$) and the increased road kill incidents in the forest compared to the village ($p < 0.05$) highlight the necessity for targeted interventions (Singh & Sharma, 2024). Addressing these specific risks through tailored conservation strategies will be crucial for mitigating wildlife mortality and enhancing the sustainability of wildlife populations.

5. Conclusion

In summary, understanding the patterns and seasonal variations in wildlife mortality is essential for developing effective conservation strategies. Targeted efforts to improve electrical safety in rural areas, manage road impacts in forested regions, and address seasonal ecological pressures are vital for protecting wildlife and ensuring the long-term health of ecosystems.

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Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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