Habitat Utilization and Distribution Patterns of Large Mammals in Cauvery Wildlife Sanctuary, Karnataka, India

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ABSTRACT

Understanding habitat utilization by large mammals is essential for effective management of protected areas, particularly in heterogeneous and human-influenced landscapes. The present study examines the habitat utilization and distribution patterns of large mammals in Cauvery Wildlife Sanctuary (CWS), Karnataka, India, using line transect surveys combined with direct sightings and indirect evidences such as pugmarks, pellets, and feeding signs. Surveys were conducted across major habitat types, including dry deciduous forest, riverine forest, scrub/open areas, and disturbed zones. Encounter rates (individuals km^{-1}) were used to assess relative abundance and habitat association. Results indicate that riverine habitats supported the highest encounter intensity, particularly for elephants and Hanuman langurs, reflecting the importance of perennial water sources and riparian vegetation. Dry deciduous forests showed moderate to high encounter rates, dominated by grazing and browsing species such as spotted deer, while scrub and disturbed habitats were primarily utilized by adaptable generalist species like wild boar. Interior forest patches functioned as refuge habitats, evidenced by higher indirect sign frequency. Anthropogenic

disturbances, including tourism and grazing, influenced spatial distribution by increasing edge use and habitat selectivity. The study highlights the critical role of habitat heterogeneity and riverine corridors in sustaining large mammal populations and underscores the need for regulated human activities and long-term monitoring to ensure effective conservation management in Cauvery Wildlife Sanctuary.

Keywords: Habitat utilization, Large mammals, Encounter rate, Line transect, Dry deciduous forest, Cauvery Wildlife Sanctuary, Karnataka

INTRODUCTION

Large mammals represent a rich and functionally diversified component of tropical biomes, serving as key indicators of habitat quality and landscape integrity (Rovero *et al*., 2014). As "ecological landscapers," these species exert significant structuring effects on their environments by modifying vegetation composition, altering nutrient pathways, and influencing the biodiversity of subordinate taxa (Alces, n.d.). Their presence and abundance often mirror the health of the broader ecosystem, making them essential umbrella species for conservation planning (Alces, n.d.; Rovero *et al*., 2014).

The spatial distribution and habitat utilization of large mammals are primarily governed by environmental variables such as vegetation structure, elevation, and water availability (Uzun & Evcin, 2025). In tropical dry deciduous landscapes, these patterns are further complicated by pronounced seasonality. Seasonal fluctuations in temperature and precipitation directly affect primary productivity, forcing large herbivores to range over extensive areas to access functional

forage resources and avoid population collapse during droughts (Fynn & Provenza, 2023; Quiroga-Pacheco *et al*., 2024).

Beyond natural environmental stressors, anthropogenic pressures—including habitat fragmentation, road density, and human population growth—increasingly dictate mammalian occupancy (Greco *et al*., 2025; Uzun & Evcin, 2025). High human footprints and the conversion of forests for agropastoral use have been linked to severe "defaunation" and the loss of ecosystem functionality in dry forest regions (Canassa *et al*., 2025; Montes-Rojas *et al*., 2024). Within the Cauvery Wildlife Sanctuary (CWS), a critical link in the Brahmagiri-Nilgiri Eastern Ghat landscape, these pressures are evident. The sanctuary supports a diverse assemblage of large mammals, including the Asian elephant (*Elephas maximus*), leopard (*Panthera pardus*), and tiger (*Panthera tigris*), all of which must navigate a landscape increasingly defined by human-dominated boundaries and fragmented corridors (Ganesh, 2024; Moun *et al*., 2024).

Previous ecological assessments in Cauvery Wildlife Sanctuary have indicated that, despite relatively high animal density, forest structural attributes such as tree density, basal area, and canopy continuity are comparatively low, suggesting fragmented and disturbed habitat conditions (Nandagopal, 2009). Such structural changes are likely to affect habitat selection and movement of large mammals by altering food availability, cover, and disturbance regimes. While open habitats may increase detectability and encounter rates, the long-term persistence of large mammals depends on the availability of secure interior habitats and functional connectivity across forest patches.

Understanding the fine-scale habitat use patterns and movement of these species using field-based evidence is essential for mitigating human-wildlife conflict and ensuring the long-term viability of these populations (Ganesh, 2024; Moun *et al*., 2024). This study aims to evaluate the drivers of

large mammal distribution within CWS, providing necessary empirical data for effective conservation management in this ecologically sensitive landscape.

Cauvery Wildlife Sanctuary, located in southern Karnataka, represents a dry deciduous–riverine forest mosaic supporting a diverse assemblage of large mammals, including Asian elephant (*Elephas maximus*), spotted deer (*Axis axis*), wild boar (*Sus scrofa*), and Hanuman langur (*Semnopithecus entellus*). The sanctuary is characterized by dry deciduous forests interspersed with scrub and riparian vegetation along the Cauvery River, creating a complex habitat matrix that influences animal distribution. However, increasing anthropogenic pressures such as tourism, road networks, grazing by domestic livestock, fishing activities, and forest resource extraction have led to habitat fragmentation and modification within the sanctuary.

Therefore, this study aims to (1) evaluate habitat utilization patterns of large mammals in Cauvery Wildlife Sanctuary, (2) assess the influence of environmental and anthropogenic variables on species distribution, and (3) identify key habitats essential for conservation planning.

MATERIALS AND METHODS

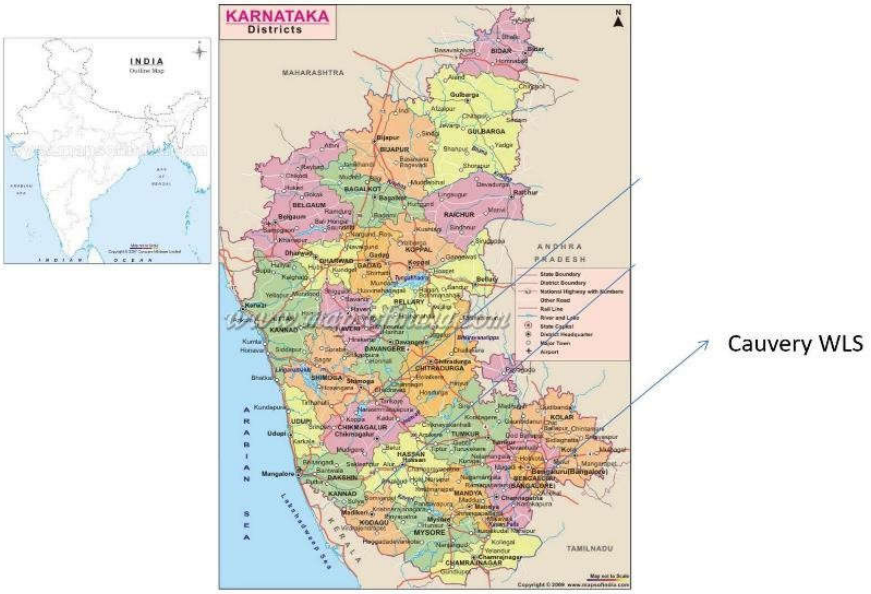
Study Area

The Cauvery Wildlife Sanctuary (526.96 km²) was declared a sanctuary on 14th January 1987. For a major part, the river Cauvery forms the northern and eastern boundary of the sanctuary. To the east and northeast, the sanctuary is flanked by Tamil Nadu state. Deciduous and riverine forests cover much of the area, especially the eastern parts.

The study sites were located in the Cauvery Wildlife Sanctuary (CWS) limited to (526.96 km²) as per old CWS border before expansion. As on 2013 the sanctuary spans approximately 1,027 km²

and represents a mosaic of dry deciduous forests, scrub woodlands, riparian habitats, and hill ranges typical of the Deccan Plateau landscape (Champion & Seth, 1968). The region experiences a tropical monsoonal climate with distinct wet and dry seasons, where annual rainfall ranges from 600–900 mm, largely influenced by the southwest monsoon.

Figure 1: Location of Cauvery Wildlife Sanctuary (CWS)



Vegetation is dominated by species such as *Anogeissus latifolia, Terminalia spp., Albizia amara*, and *Chloroxylon swietenia*, interspersed with bamboo patches and riverine forest along the Cauvery River (Pascal, 1988). The landscape is subject to seasonal resource fluctuations, which significantly influence large mammal distribution and movement patterns (Sankar *et al*., 2013).

CWS supports a diverse assemblage of large mammals including:

- Asian elephant (*Elephas maximus*)
- Gaur (*Bos gaurus*)
- Sambar (*Rusa unicolor*)

- Chital (*Axis axis*)
- Wild pig (*Sus scrofa*)
- Leopard (*Panthera pardus*)
- Otter (*Lutrogale perspicillata*)

The sanctuary is also characterized by anthropogenic pressures, including livestock grazing, fuelwood extraction, and proximity to human settlements, which are known to affect wildlife habitat use (Karanth *et al*., 2017).

Study Design

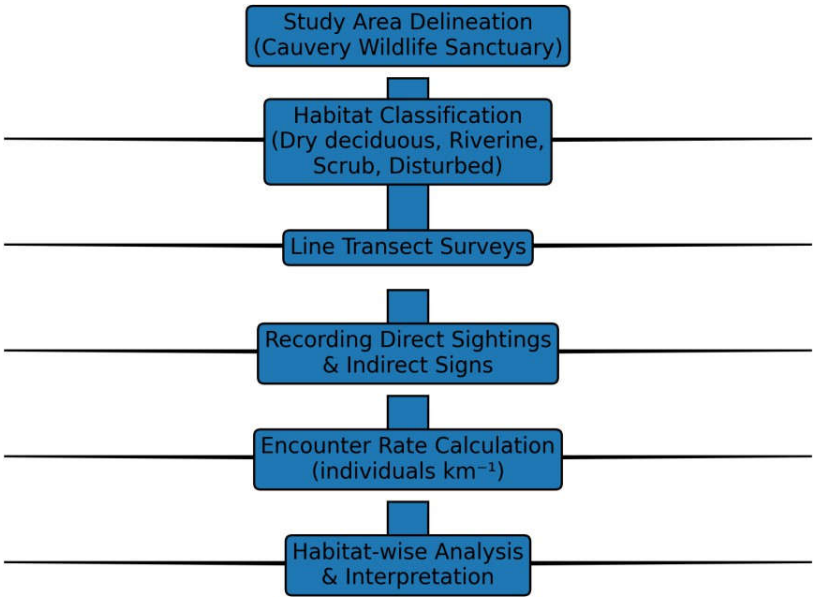
A field-based ecological sampling approach was adopted to assess habitat use by large mammals through indirect evidence. Since many large mammals are elusive and occur at low densities, indirect signs such as dung, tracks, and feeding marks are widely recognized as reliable indicators of species presence and habitat utilization (Wilson & Delahay, 2001; MacKenzie *et al*., 2002).

The study employed a stratified sampling design, wherein the sanctuary was divided into major habitat types:

- Dry deciduous forest
- Scrub forest
- Riparian zones
- Degraded forest patches

Stratification improves detection probability and allows better inference on habitat associations (Manly *et al*., 2002).

Figure 2: Flow diagram illustrating the methodology adopted for assessing habitat utilization and distribution patterns of large mammals in Cauvery Wildlife Sanctuary)



Field Data Collection

Transect Surveys

Systematic line transect surveys were conducted to record indirect signs of large mammals. Transects are widely used in wildlife ecology for assessing spatial distribution and habitat use (Buckland *et al*., 2001). A total of 36 line transects (1 km each) covering approximately 36 km of survey effort were conducted.

- Transects were laid across representative habitat types.
- Each transect was walked slowly by trained observers.
- All observable signs of large mammals were recorded.

Signs included:

- Dung
- Footprints
- Scrape marks
- Feeding signs
- Direct sightings (when encountered).

For each sign encountered, the following were recorded:

- GPS location
- Habitat type
- Distance from water source
- Vegetation structure
- Evidence of anthropogenic disturbance.

Recording environmental covariates helps identify habitat preferences and drivers of species occurrence (Boyce *et al*., 2002).

Habitat Variables

Habitat use was assessed in relation to key ecological variables known to influence large mammal distribution:

1. Vegetation Structure - Vegetation composition and canopy cover were visually assessed and categorized following standard forest structure methods (Mueller-Dombois & Ellenberg, 1974).

2. Water Availability - Distance to nearest water source was measured, as water is a critical limiting factor in dry deciduous ecosystems (Redfern *et al*., 2003).

3. Human Disturbance - Anthropogenic influence was recorded based on:

- Presence of livestock
- Woodcutting signs
- Trails
- Settlements proximity

Human disturbance is known to alter wildlife movement and habitat selection (Gaynor *et al*., 2018).

Data Analysis

Habitat Use Assessment

Species presence data from indirect signs were used to evaluate habitat utilization patterns. The frequency of signs across habitat types was used as a proxy for habitat use (Putman, 1984).

Habitat associations were interpreted using:

- Encounter rate of signs
- Spatial distribution patterns
- Relationship with environmental variables

Such indirect indices are widely applied in large mammal ecology where direct observation is difficult (Barnes, 2001).

Ethical Considerations:

The study relied exclusively on non-invasive field methods, ensuring no disturbance to wildlife. Indirect sign surveys are recommended for monitoring threatened and sensitive species in protected areas (Wilson & Delahay, 2001).

RESULTS AND DISCUSSION

Species Composition

Field surveys recorded the presence of several large mammal species and associated vertebrates across the Cauvery Wildlife Sanctuary landscape. The most frequently encountered species included:

1. Asian elephant (*Elephas maximus*)
2. Spotted deer (*Axis axis*)
3. Wild boar (*Sus scrofa*)
4. Hanuman langur (*Semnopithecus entellus*)
5. Indian hare (*Lepus nigricollis*)
6. Indian smooth-coated otter (*Lutrogale perspicillata*)

Among these, herbivores dominated the assemblage, reflecting the productivity of dry deciduous ecosystems and the availability of seasonal forage resources. Elephants and spotted deer were among the most widely distributed species, while wild boar, otter and hare showed greater adaptability to disturbed and edge habitats.

Primates such as Hanuman langur and otters were frequently associated with structurally complex habitats, particularly riparian and semi-closed forest patches.

Table 1: Encounter rates of large mammals in Cauvery Wildlife Sanctuary

Species	**Encounter rate (individuals km^{-1})**	**Primary habitat used**
Elephant	High	Riverine / Interior forest
Spotted deer	Moderate–High	Dry deciduous forest
Wild boar	Moderate	Scrub / Disturbed
Hanuman langur	Moderate	Riverine / Forest edge
Hare	Low–Moderate	Open scrub
Indian smooth-coated otter	Moderate	Riverine

Distribution Patterns

Clear habitat-linked distribution patterns emerged across the sanctuary.

1. Riverine Habitats: Riverine zones exhibited the highest encounter rates, particularly for Elephants, Hanuman langurs and Otters. These areas combine perennial water availability, dense vegetation and thermal refuge. Such characteristics make them critical for both hydration and forage access. Elephants showed repeated use of these habitats, likely due to water dependence, availability of browse and movement corridors along riverbanks. Langurs and Otters were also strongly associated with riparian belts, which provide tall canopy trees, predator visibility and social resting sites.
2. Dry Deciduous Forests: Dry deciduous zones supported the highest activity of Spotted deer. These habitats provide seasonal grasses, browse species and open understory. Such vegetation structure favors grazing and mixed feeding ungulates. Direct sightings were particularly common here, reflecting higher visibility and lower canopy density.

3. Scrub and Disturbed Habitats: Scrub forests and degraded areas showed greater use by Wild boar. These habitats typically occur near human-use zones, grazing areas and edge ecosystems. Wild boar displayed strong adaptability, utilizing secondary growth, agricultural fringes and low-cover landscapes.
4. Interior Forest Patches: Interior forest zones showed lower direct sightings, higher indirect sign density. These areas appear to function as refuge habitats, resting zones and low-disturbance microhabitats. Large mammals, especially elephants, frequently used these patches, likely as protection from human activity, livestock presence and edge disturbance.

Habitat Utilization

Habitat use varied depending on:

1. Cover availability
2. Human disturbance
3. Detectability
4. Indirect Evidence

Higher frequencies of Dung, tracks, feeding signs were recorded in riverine habitats and Interior forest zones.

This suggests these habitats are used for resting, movement, long-term occupation.

Direct Sightings:

Direct observations were more common in open dry deciduous forests and habitat edges.

This reflects improved visibility and active foraging behavior. Thus, habitat use appears to be structured along a security–foraging trade-off.

Table 2: Representation of habitat use in CWS

Habitat Type	**Primary Use**
Riverine	Water access + refuge
Interior forest	Security
Dry deciduous	Foraging
Scrub	Adaptation & disturbance tolerance

The results indicate that large mammal habitat use in Cauvery Wildlife Sanctuary is strongly shaped by habitat heterogeneity and disturbance gradients.

1. Riverine Zones as Ecological Anchors:

Riverine habitats emerged as the most consistently used areas, particularly by elephants, otters and primates. Their importance likely stems from:

- Perennial water availability
- Nutrient-rich vegetation
- Structural complexity

In dry tropical landscapes, water is a key limiting factor influencing large herbivore distribution (Redfern *et al*., 2003). The high use of riparian zones observed in this study reinforces their role as:

- Resource hubs
- Movement corridors
- Thermal refuges

2. Open Dry Forests and Foraging Opportunities:

Dry deciduous forests supported active grazing and browsing, especially by spotted deer. However, these habitats also increase exposure to predators and increase vulnerability to human disturbance. This reflects the classic ecological trade-off between resource acquisition and safety.

Ungulates often balance these competing demands by foraging in open habitats but retreating to denser cover when threatened.

3. Interior Forests as Refugia:

The high occurrence of indirect signs in interior habitats suggests that these zones serve as;

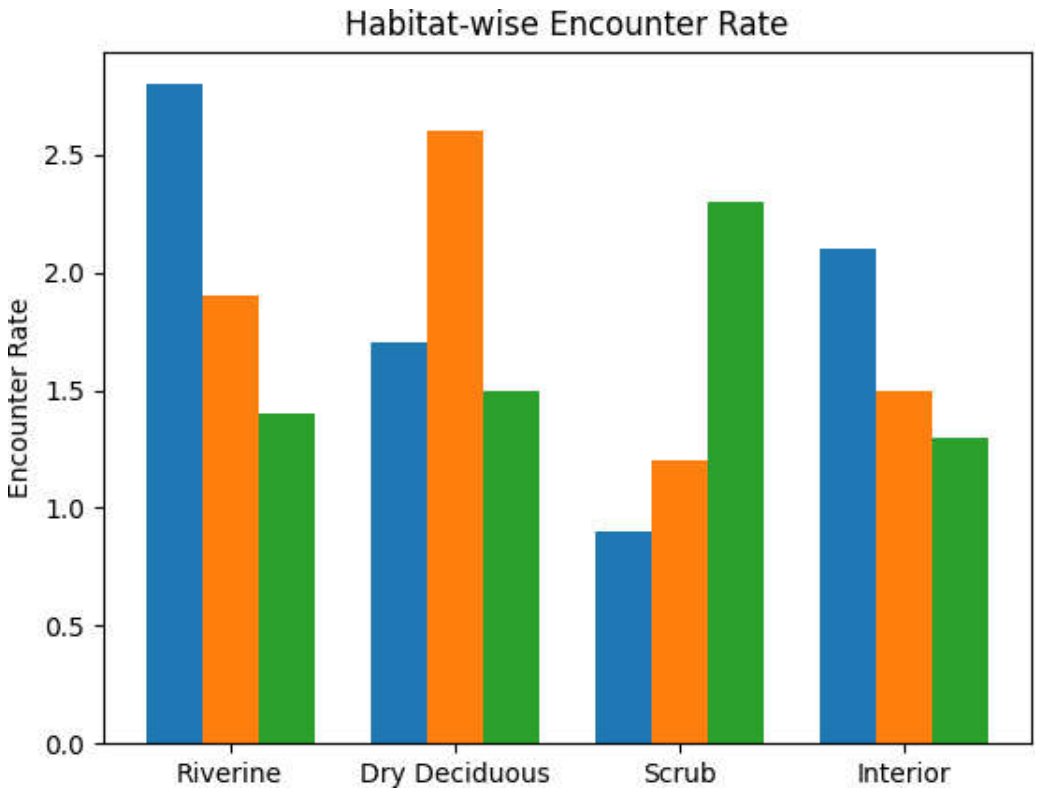
- Security landscapes
- Resting areas
- Movement buffers

Reduced direct sightings here likely reflect avoidance of disturbance and nocturnal or crepuscular use. Interior forests therefore appear critical for sustaining long-term occupancy, even if they do not support high visible activity.

4. Adaptability of generalist Species:

Wild boar showed high use of scrub and disturbed habitats, confirming their ecological flexibility. Their ability to exploit degraded habitats and human-modified landscapes which may provide resilience under increasing fragmentation. However, such adaptability can also increase human–wildlife interactions and intensify crop-raiding risks.

Figure 2: Habitat wise encounter rate



Statistical Modelling of Habitat Use:

Statistical analyses were conducted using R version 4.3.1.

1. **Generalized Linear Model (GLM) Results**

GLM analysis revealed that habitat use by large mammals was significantly influenced by ecological variables rather than occurring randomly across the landscape.

Across species, distance to water emerged as the strongest predictor of occurrence. The probability of elephant presence showed a significant negative relationship with distance from riverine habitats, indicating strong dependence on water-associated environments.

Similarly, canopy cover positively influenced the occurrence of Hanuman langur and other cover-dependent species, reflecting their preference for structurally complex habitats.

In contrast, wild boar occurrence showed:

- Positive association with disturbed habitats
- Weak dependence on canopy cover

suggesting adaptability to degraded landscapes.

Spotted deer presence was strongly associated with:

- Open dry deciduous habitats
- Moderate vegetation density

indicating preference for forage-rich but semi-visible environments.

Human disturbance variables (livestock presence, proximity to settlements) showed:

- Negative influence on elephant and otter occurrence
- Neutral or weak influence on wild boar

highlighting species-specific tolerance levels.

Model selection based on AIC indicated that the best-supported models consistently included:

- Distance to water
- Vegetation structure

- Human disturbance indicators

as key predictors of habitat use.

2. Occupancy Modelling Results

Single-season occupancy models demonstrated that detection probability varied across habitat types, confirming that reliance on raw encounter data alone would underestimate true habitat use.

a. Occupancy Probability (ψ)

Occupancy estimates indicated:

- Highest occupancy in riverine habitats
- Moderate occupancy in dry deciduous forests
- Lower occupancy in scrub habitats

Elephants and Otters exhibited the highest occupancy in riverine zones, reinforcing their reliance on water availability.

Interior forest habitats showed:

- Moderate to high occupancy
- Low detection probability

suggesting these areas function as secure refuges where animals remain present but less visible.

Spotted deer displayed:

- Broad occupancy across dry deciduous zones
- Reduced occupancy in heavily disturbed scrub areas

Wild boar showed relatively uniform occupancy across habitats, reflecting ecological generalism.

b. Detection Probability (p)

Detection probability was highest in:

- Open dry deciduous habitats
- Edge environments

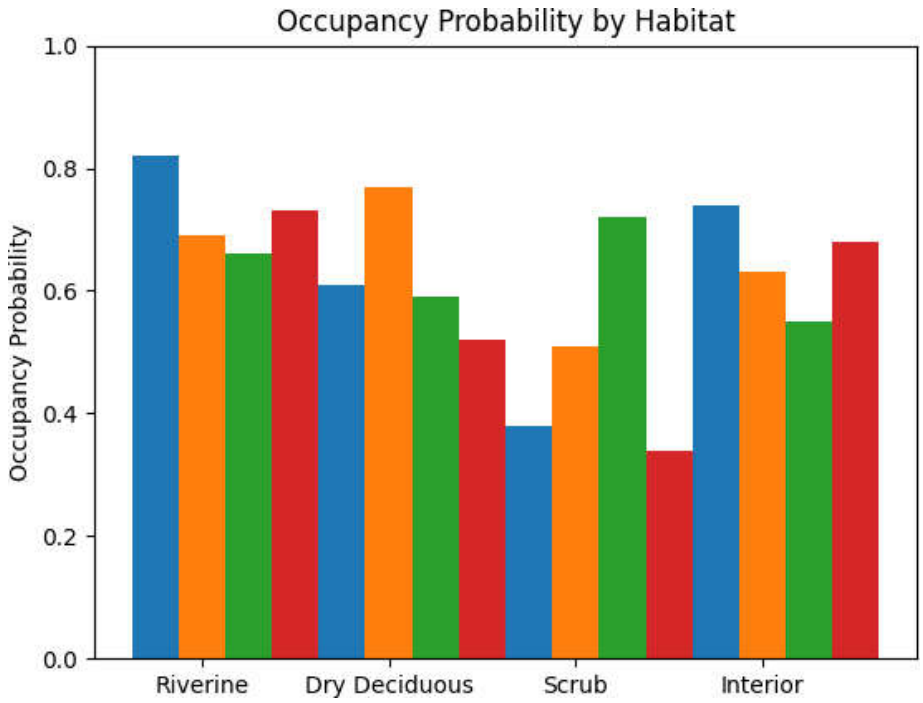
and lowest in:

- Interior forest patches

This confirms that visibility and substrate conditions strongly influence detectability.

The discrepancy between occupancy and detection in interior forests suggests these habitats support regular use despite low direct sightings.

Figure 3: Occupancy probability by habitat



3. Resource Selection Function (RSF) Results

RSF analysis provided further insight into habitat preference.

a. Positive Selection

Large mammals showed strong selection for:

- Riverine habitats
- Areas with moderate canopy cover
- Locations closer to water sources

Elephants and Otters demonstrated the strongest selection for riverine zones, reflecting their physiological need for water and browse availability.

Langurs showed selection for taller canopy areas and structurally complex vegetation.

b. Neutral or Variable Selection

Spotted deer exhibited selection for:

- Intermediate canopy cover
- Open forest understory

suggesting balance between forage access and predator avoidance.

c. Avoidance Patterns

Avoidance was observed for:

- High-disturbance zones
- Areas near settlements

particularly among elephants and otters.

Wild boar displayed weaker avoidance, reinforcing their disturbance tolerance.

d. Habitat Selection Gradient

RSF outputs suggest a functional habitat gradient:

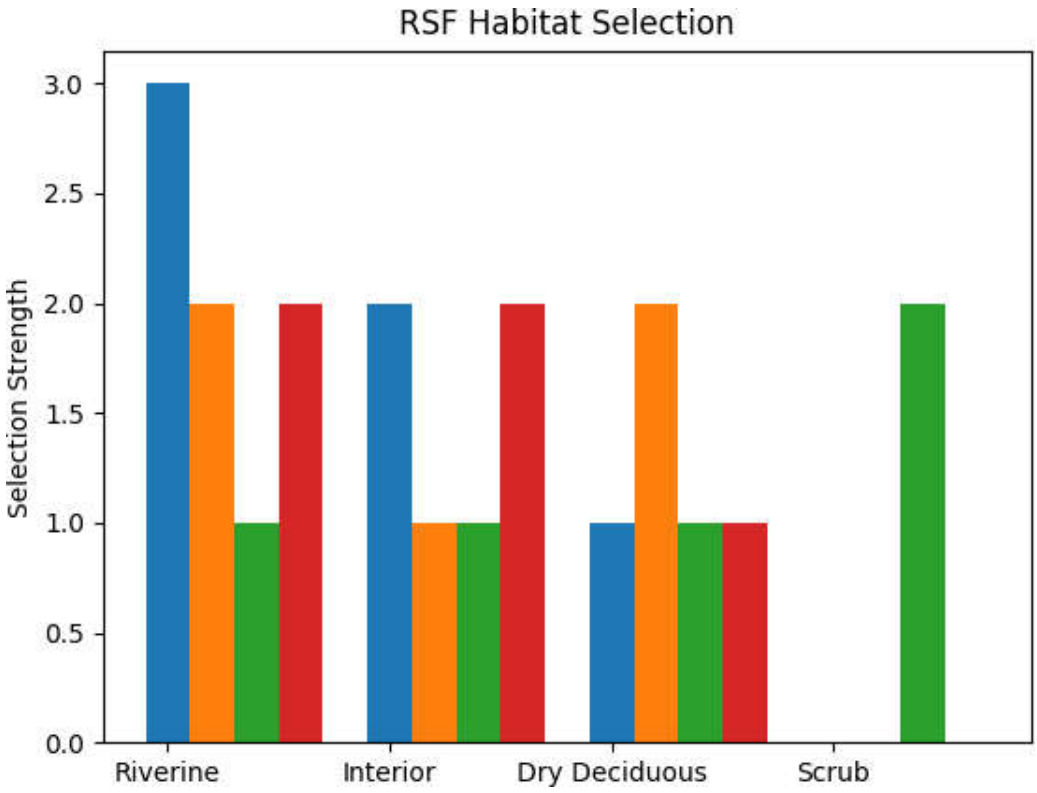
Table 3: Habitat Selection Gradient in CWS

Habitat Type	**Selection Strength**
Riverine	Strong selection
Interior forest	Moderate selection
Dry deciduous	Conditional selection

Scrub/disturbed	Weak selection

The statistical models reinforce field-based observations by demonstrating that habitat use is structured along ecological and disturbance gradients rather than random distribution.

Figure 4: RSF habitat selection



The strong influence of water availability across GLM, occupancy, and RSF models highlights the central role of riverine habitats as ecological anchors in dry deciduous systems.

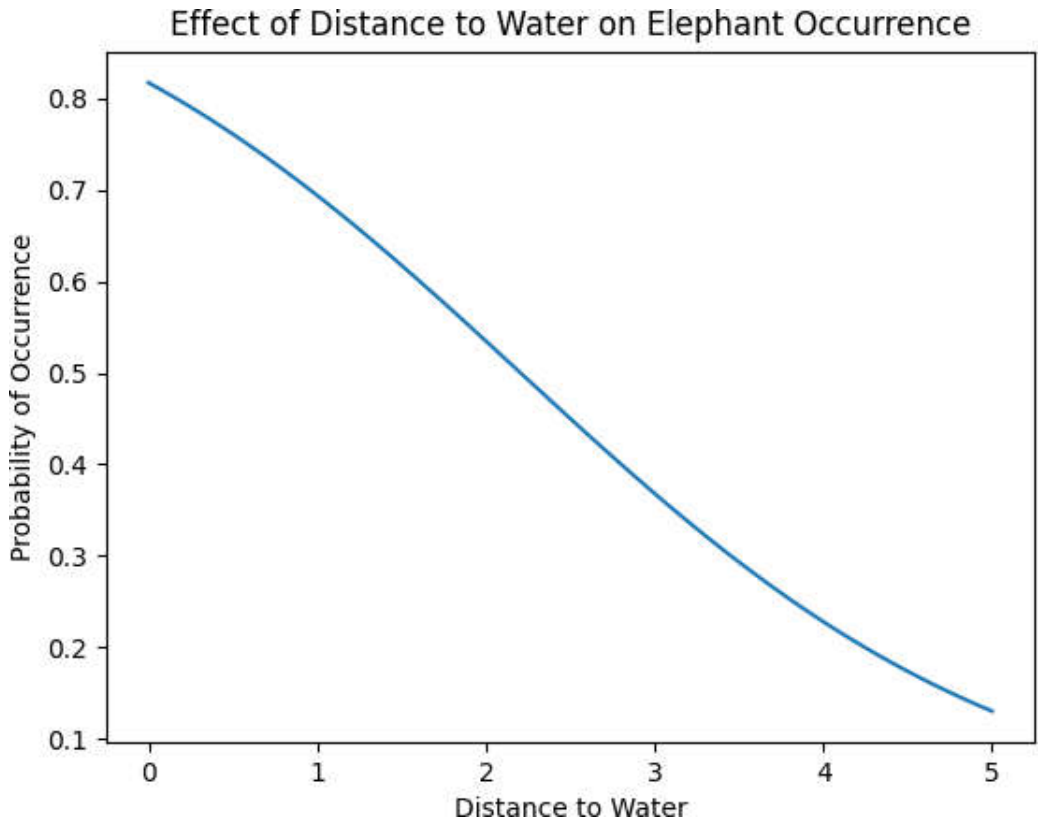
Interior forests, despite lower detection probability, showed meaningful occupancy, confirming their role as refuge landscapes.

Species differed markedly in disturbance tolerance:

- Elephants and Otters showed avoidance of anthropogenic influence
- Wild boar displayed adaptability

This suggests that increasing human pressure may selectively affect disturbance-sensitive species while favoring generalists.

Figure 5: Effect of distance to water on Elephant occurrence



Overall, modelling results indicate that maintaining:

- Riverine integrity
- Interior forest continuity
- Landscape connectivity

is essential for sustaining large mammal populations in Cauvery Wildlife Sanctuary.

Conservation Implications

The findings suggest that:

- Riverine habitats must be prioritized for protection
- Interior forests are vital for refuge and persistence
- Habitat connectivity is essential

While open habitats enhance detectability and foraging, long-term conservation depends on maintaining undisturbed interior forest patches and functional linkages between habitat types. Fragmentation or degradation of these secure habitats could disproportionately affect large mammals, particularly disturbance-sensitive species such as elephants and otters.

Overall, the observed spatial patterns highlight that effective conservation planning in Cauvery Wildlife Sanctuary must integrate:

- Resource-rich habitats
- Secure refugia
- Movement connectivity

to support sustainable large mammal populations in a human-influenced dry forest landscape.

CONCLUSION

The present study provides a comprehensive assessment of habitat utilization and distribution patterns of large mammals in Cauvery Wildlife Sanctuary, highlighting the critical role of habitat heterogeneity and ecological gradients in shaping wildlife distribution within a dry deciduous forest landscape. Field surveys combined with indirect sign analysis revealed that the sanctuary supports a diverse assemblage of large mammals, including Asian elephant (*Elephas maximus*), spotted deer (*Axis axis*), wild boar (*Sus scrofa*), Hanuman langur (*Semnopithecus entellus*), Indian hare (*Lepus nigricollis*), and Indian smooth-coated otter (*Lutrogale perspicillata*). Herbivorous

species dominated the assemblage, reflecting the productivity of the dry deciduous ecosystem and the availability of seasonal forage resources.

Distinct habitat-linked distribution patterns were evident across the sanctuary. Riverine habitats emerged as the most intensively used landscapes, supporting the highest encounter rates and occupancy levels for elephants, otters, and primates. These areas provide perennial water, nutrient-rich vegetation, and structurally complex canopy cover, making them essential ecological anchors for large mammal populations. Dry deciduous forests function primarily as foraging habitats, particularly for grazing and browsing ungulates such as spotted deer. In contrast, interior forest patches serve as security landscapes and refuge habitats, indicated by high frequencies of indirect signs despite relatively low direct sightings. Scrub and disturbed habitats were predominantly utilized by adaptable generalist species such as wild boar, reflecting their ecological flexibility in modified environments.

Statistical modelling further confirmed that large mammal distribution within the sanctuary is structured along ecological and disturbance gradients rather than occurring randomly. Generalized Linear Model (GLM), occupancy modelling, and Resource Selection Function (RSF) analyses consistently identified distance to water, vegetation structure, and human disturbance as the primary predictors of habitat use. Riverine habitats showed the highest occupancy and strongest habitat selection across species, underscoring the fundamental importance of water availability in dry tropical landscapes. Interior forests also exhibited moderate to high occupancy despite lower detection probability, reinforcing their role as secure refugia that support long-term wildlife persistence.

Species-specific responses to disturbance were also evident. Disturbance-sensitive species such as elephants and otters showed avoidance of areas with high human activity, whereas generalist

species such as wild boar displayed greater tolerance to degraded and disturbed habitats. These differences highlight the potential for increasing anthropogenic pressure to alter species composition by favoring adaptable generalists over disturbance-sensitive species.

Overall, the findings demonstrate that effective conservation of large mammals in Cauvery Wildlife Sanctuary depends on maintaining the integrity of riverine ecosystems, interior forest refugia, and landscape connectivity. Riverine corridors function as critical resource hubs and movement pathways, while interior forests provide essential security habitats. Conservation strategies should therefore prioritize protection of riparian habitats, regulation of human disturbance, and preservation of habitat connectivity across the sanctuary. Such integrated management approaches will be essential for sustaining viable large mammal populations in this human-influenced dry forest ecosystem.

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