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Cover: Digital illustration of *Impatiens chamchumroonii* in Krita by Dupati Poojitha.



Population status and habitat use of Indian Grey Wolf *Canis lupus pallipes* in Pench Tiger Reserve, Madhya Pradesh, India

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Abstract: Wolves, once one of the most widely distributed carnivores on Earth, have experienced drastic population declines and range contractions due to anthropogenic pressures. We studied the population status and habitat utilization of the Indian Grey Wolf in Pench Tiger Reserve (PTR). Both direct and indirect evidence were used to assess wolf presence, and Bonferroni confidence intervals were calculated to analyze habitat utilization. Wolf distribution was found to be restricted to the Khawasa Range of PTR, with the Khawasa Beat showing the highest encounter rate (0.154/km). Most wolf signs were recorded in mixed habitats (miscellaneous), underscoring the importance of these areas for the species' long-term conservation. A significant positive correlation was observed between tree-cutting and wolf encounter rate ($r = 0.976$, $p = 0.024$, $df = 3$), suggesting that habitat changes associated with tree removal may influence wolf activity.

Keywords: Anthropogenic pressures, Bonferroni confidence intervals, buffer zone, camera trap, carnivores, correlation, direct and indirect evidence, encounter rate, grazing, tree-cutting.

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Author contributions: Concept and design of study IR and SK. Supervision: SK. Data collection: IR. Analysis: IR and SK. Manuscript writing IR, Manuscript review and comments: IR and SK.

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INTRODUCTION

The Grey Wolf *Canis lupus*, the largest member of the canid family, inhabits a wide range of terrestrial ecosystems (Mech 1974; Jhala & Giles 1991). Its global distribution spans across 68 countries, making it one of the most widely distributed terrestrial mammals (Boitani et al. 2020). Among the 10 subspecies of Grey Wolf recognized worldwide (Boitani et al. 2020; Werhahn 2020), India harbors two distinct subspecies: the Himalayan or Tibetan Wolf *Canis lupus chanco* and the Indian Grey Wolf or Indian Peninsular Wolf *Canis lupus pallipes* (Aggarwal et al. 2003; Sharma et al. 2004). The Indian Grey Wolf is a keystone carnivore of India's semi-arid and grassland ecosystems. Despite its ecological significance, the taxon remains one of the least studied large carnivores in the country, often overshadowed by charismatic megafauna such as the elephant, tiger, and leopard. In India, the Indian Grey Wolf is protected under Schedule I of the Wildlife (Protection) Act, 1972 and is listed as 'Vulnerable' by the IUCN as its populations are considered fragmented and declining due to increasing anthropogenic pressures (IUCN 2025).

Over the past few decades, the global decline of large carnivores has emerged as a critical conservation issue, with many species experiencing significant range contractions and population losses (Weber & Rabinowitz 1996; Ripple et al. 2014; Fernández-Sepúlveda & Martín 2022). The Indian Grey Wolf is no exception, having suffered a substantial decline across much of its historical distribution (Mech 1970). This decline has been largely attributed to habitat degradation, increasing human-wolf negative interactions, low public awareness, and in some areas, targeted persecution and extermination campaigns (Habib 2007). The estimated population of the Indian Grey Wolf in India is around 3,170 individuals (Jhala et al. 2022), distributed across fragmented habitats with little to no connectivity between metapopulations. This highlights the urgent need for region-specific conservation strategies tailored to local ecological and sociopolitical contexts. It is estimated that India has a total of 89,138 km² suitable habitats for breeding packs; the largest continuous breeding habitat is located in the Central Indian landscape (Jhala et al. 2022). The remaining populations of the Indian Grey Wolf are small, fragmented, and increasingly isolated, making them highly vulnerable to local extinction. Without targeted management interventions and scientific understanding of their population status and habitat needs, the long-term viability of these populations remains at risk (Singh & Kumara 2006; Becker et al. 2008).

Reliable information on population size and habitat use is essential for the effective conservation of any threatened species (Sousa-Silva et al. 2014). Acquiring such data is particularly challenging for species like the Indian Grey Wolf, which occur at low densities and inhabit vast, human-dominated landscapes (Mahajan et al. 2022a). Although several studies have assessed the species' status at local and regional scales (Jhala & Giles 1991; Kumar & Rahmani 1997; Kumar 1998; Singh & Kumara 2006), and a few at the national level (Shahi 1982; Jhala 1993, 2003; Karanth et al. 2009; Srivathsa et al. 2020; Jhala 2022), knowledge gaps still persist regarding their ecological preferences across different landscapes.

Pench Tiger Reserve (PTR), located in the Satpura-Maikal landscape of central India, is a known stronghold for apex predators like the Bengal Tiger *Panthera tigris* and Leopard *Panthera pardus*. However, its role as a habitat for lesser-known carnivores such as the Indian Grey Wolf is poorly understood. Understanding the population status and habitat utilization patterns of the Indian Grey Wolf in a multi-use landscape of PTR is crucial for informed conservation and management efforts. This study aims to assess the current distribution and habitat preferences of the Indian Grey Wolf within Pench Tiger Reserve, Madhya Pradesh. By identifying key habitats and anthropogenic influences, the findings will contribute to evidence-based strategies for the conservation of this ecologically important yet vulnerable carnivore.

MATERIAL AND METHODS

Study Area

The study was conducted in PTR, located in the central Indian state of Madhya Pradesh (Figure 1). The Reserve spans an area of 1,179.63 km² and falls within the Seoni and Chhindwara districts. Geographically, PTR lies between 78.916–79.583 °E and 21.583–22.000 °N. The elevation ranges 425–600 m. Although some areas like the Karmajhiri Range are plains, the majority of PTR's terrain is characterized by gently undulating landscapes interspersed with seasonal streams and 'nallahs'. The region experiences a wide temperature range, from 0°C in winter to 45°C in summer (Sankar et al. 2000), with an average annual rainfall of approximately 1,300 mm. The climate is marked by four distinct seasons: summer (March–June), monsoon (July–August), post-monsoon (September–November), and winter (December–February).

The vegetation in Pench Tiger Reserve is

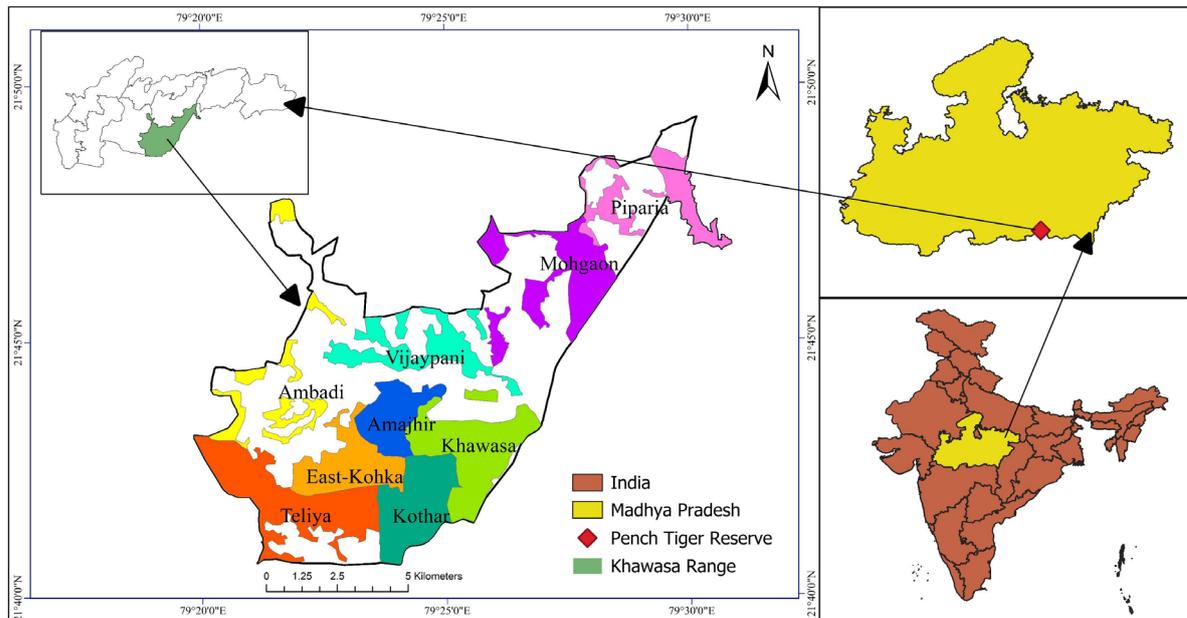


Image 1. Map depicting the location of study area: Khawasa Range, Pench Tiger Reserve, Madhya Pradesh.

predominantly composed of dry deciduous forests, comprising pure Teak *Tectona grandis* forest, Teak-mixed forest, mixed forests, bamboo forest, and open grasslands. The reserve supports a diverse assemblage of carnivores, including the Tiger, Leopard, Dhole *Cuon alpinus*, Jungle Cat *Felis chaus*, Small Indian Civet *Viverricula indica*, Sloth Bear *Melursus ursinus*, Golden Jackal *Canis aureus*, Indian Grey Wolf, and Common Palm Civet *Paradoxurus hermaphroditus*. The herbivore community includes species such as the Sambar *Rusa unicolor*, Chital or Spotted Deer *Axis axis*, Gaur *Bos gaurus*, Nilgai *Boselaphus tragocamelus*, and Chousingha or Four-horned Antelope *Tetracerus quadricornis*. In addition to mammals, the reserve hosts a rich diversity of birdlife, with over 250 recorded species.

Methods

Camera-trapping data in 2019–2023 were collected from the forest department of Pench Tiger Reserve. Data analysis revealed the presence of the Indian Grey Wolf exclusively in the Khawasa Range of the Reserve. Accordingly, the Khawasa Range was selected for further data collection (January–March 2023) on population status and habitat use of wolves. The range is a multi-use area of the Reserve and predominantly characterized by tropical dry deciduous forest. The vegetation is dominated by Teak along with associated species such as Mahua *Madhuca indica*, Saja *Terminalia tomentosa*, and Tendu *Diospyros melanoxylon*. The range experiences

moderate level of human disturbance like livestock grazing, tree-lopping, and the seasonal collection of forest products like Mahua flowers and Tendu leaves. The range comprises nine forest beats, each of which was chosen as a sampling unit to assess the population status and habitat utilization patterns of the species.

Wolf status and habitat use across forest beats were assessed by systematically searching for and recording both direct and indirect evidences of wolves. Surveys were conducted along all trails, roads, and nallahs within the different beats, as these features are commonly used by wolves for movement within their home ranges. Survey efforts involved walking 171 km² across these features. This approach increases the probability of detecting wolf evidence compared to random surveys (Mahajan et al. 2022b). To minimize bias arising from misidentification, only fresh signs were recorded during the survey.

Whenever direct or indirect evidence of wolves was encountered, data on evidence type, location, habitat, terrain and status of anthropogenic pressures were collected. To differentiate indirect evidence of the Indian Grey Wolf from those of related sympatric species such as the Domestic Dog *Canis familiaris* and Golden Jackal *Canis aureus*, we compared pugmarks, scats, and associated field signs during surveys. Wolf pugmarks are large (7–10 cm in length), oval and symmetrical shape with a straight posterior margin of the heel pad, whereas dog tracks are more variable in

size, often rounder and asymmetrical with prominent claw impressions, and jackal tracks are smaller (4.5–6 cm), compact, and narrower (Talwar & Usmani 2005; Mahajan et al. 2022b). Scats were distinguished based on size, shape, and contents. The wolf scats are thick (2–3 cm diameter), rope-like, and generally contained hair, bones, and prey remains; dog scats are irregular, softer, and often contained anthropogenic matter; jackal scats are smaller (1.5–2 cm diameter), segmented, and frequently contained fruit seeds in addition to hair (Jhala 2003; Rather 2021; Mahajan et al. 2022b). Data from camera-trapping and evidence surveys were used for the analysis of habitat use.

To quantify habitat conditions and habitat use, random sampling plots were laid in each beat. For the tree-layer assessment, a circular plot with a 10-m radius was used. Within this, a nested 5-m radius circular plot was laid to assess the shrub layer following Haleem & Ilyas (2023). The data collected from these plots were used to quantify vegetation characteristics, including species density, diversity, richness, and evenness, which were then used to understand patterns of wolf habitat utilization. The area under different habitat types was determined using Remote sensing and geographic information system (GIS) analysis based on the land use and land cover (LULC) map of the study area.

Analysis

The trails were monitored once, covering a total distance of 171 km. Beat-wise encounter rates were calculated by dividing the total number of wolf evidence recorded in each beat by the total distance travelled within that beat (Table 1). To evaluate the relationship between anthropogenic pressures and wolf presence, non-parametric correlation analysis was conducted using SPSS version 22.0 (IBM Corp 2013). Vegetation attributes, including tree and shrub diversity, richness, and evenness, were computed using PAST software.

Data on direct and indirect wolf evidence were segregated by habitat type. A chi-square test was performed to examine whether the distribution of wolf evidence differed significantly among the various

habitat types. To assess habitat use patterns by wolves, Bonferroni confidence intervals were calculated (Neu et al. 1974; Byres et al. 1994). Habitat preferences and avoidance were determined based on these intervals.

RESULTS

Over the past five years, a total of 27 camera-trap captures of the Indian Grey Wolf were recorded in the Khawasa Range. The camera trap data revealed the presence of wolves in six out of nine beats of Khawasa range: Kothar, Amajihri, Amabari, Teliya, Vijaypani, and Khawasa. No wolf detections were recorded in East Kohka, Mohgaon, and Pipariya beats. Among the beats where wolves were captured, Kothar Beat recorded the highest number of captures, while Amajihri and Teliya had the lowest (Figure 2).

A total of 13 direct and indirect signs of Indian Grey Wolf presence were recorded during the sign survey, confirming their occurrence in only four out of the nine beats of the Khawasa Range. The highest encounter rate was recorded in the Khawasa Beat (0.15 evidences/km), while the lowest was in Pipariya Beat (0.12 evidences/km) (Table 1). The analysis of anthropogenic pressures in beats with wolf presence revealed varying intensities of human activities. The highest tree-logging was recorded in Pipariya Beat (95 trees/ha) while the lowest was in Khawasa Beat. The highest tree-cutting was recorded in Khawasa (81.9 trees/ha), whereas Pipariya Beat had the lowest tree-cutting. The highest intensity of grazing was recorded in Vijaypani while there was no grazing in Aamajhiri (Table 1). No significant correlation was observed between the wolf encounter rate and most anthropogenic pressures, except for tree-cutting, which showed a strong positive correlation with encounter rate ($r = 0.976, p = 0.024, df = 3$).

In terms of shrub composition, Ambari had the highest shrub diversity (1.673), while East Kohka showed the highest shrub richness (1.593), and Ambari again had the highest shrub evenness (0.7608). Conversely,

Table 1. Status of the anthropogenic pressures in beats with wolf presence in Pench Tiger Reserve.

Beats	Wolf encounter rate (evidence/km)	Tree-logging density (ha)	Tree-cutting density (ha)	Cattle dung piles density (ha)
Khawasa	0.154	40.9	81.9	22.7
Aamajhiri	0.137	47.8	15.9	0.0
Pipariya	0.121	95.5	15.9	79.6
Vijaypani	0.141	63.7	31.8	111.5

the lowest shrub diversity was observed in Kothar (1.022), lowest richness in Mohgaon (1.027), and lowest evenness in Kothar (0.3968) (Table 2).

Habitat-wise comparison of vegetation parameters revealed that the mixed habitat (Miscellaneous Forest) had the highest tree diversity (2.84), richness (4.345) and evenness (0.5351), which indicates species in mixed habitats are more evenly distributed than in Teak and Teak-mixed habitat (Table 3). Analysis of 40 wolf evidences (including camera-trap captures) across three habitat types – mixed, teak mixed, and teak – revealed that the majority of evidence (32) was recorded from mixed habitat, while Teak and Teak-mixed habitats each had four evidences. A chi-square test indicated no statistically significant difference in habitat utilization by the Indian Grey Wolf ($\chi^2 = 4.9$, $df = 2$, $p = 0.05$), although the test statistic was close to the critical value. To further assess habitat preference, Bonferroni confidence intervals were calculated (Table 3). The results suggested that Teak habitat was utilized less than its availability, whereas mixed and Teak-mixed habitats were used in proportion to their availability.

DISCUSSION

This study revealed that the distribution of the Indian Grey Wolf in PTR is restricted to the Khawasa Range, which lies in the buffer zone, with most sightings occurring near human settlements. Their absence from the core area and exclusive presence in the buffer zone aligns with findings by Jhala et al. (2022), who suggest that wolves prefer habitats with low to moderate densities of dominant predators such as tigers and leopards. This avoidance may be attributed to the high density of tigers and leopards in the core zone of the

study area, indicating that wolves actively avoid areas dominated by larger carnivores. The proximity of wolf sightings to human settlements suggests opportunistic behaviour, likely driven by availability of livestock carcasses and anthropogenic waste near human settlements, an adaptive trait also documented in other studies (Jethva & Jhala 2004; Becker et al. 2008; Sharma et al. 2019). By utilizing consistent and energy-efficient food sources such as livestock carcasses and human waste, wolves may compensate for limited access to wild prey resulting from interference or competition with dominant carnivores (Becker et al. 2008).

Habitat composition also plays a significant role in influencing wolf distribution in the study area. Results of the study indicate a preference for mixed and Teak-mixed forest types, which provide both concealment and prey opportunities. These habitats tend to support higher densities of herbivores due to their diverse ground vegetation and structural complexity (Karanth & Sunquist 1995), thereby indirectly benefiting wolves.

The significant positive correlation between tree-cutting and wolf encounter rate indicates that higher tree felling is associated with increased wolf activity. Tree-cutting creates open spaces and such areas also have more dirt roads and trails, which may facilitate wolf movement and improve hunting efficiency by increasing prey visibility and accessibility. Additionally, tree-cutting can enhance the growth of ground vegetation (shrub and herb layers). This improved ground cover may further contribute to habitat suitability by supporting higher prey abundance and enhancing foraging opportunities for wolves. This pattern highlights the species' ability to exploit human-modified habitats. Similar findings have been reported in other studies, where wolves were observed to use logging roads, clear-cuts, and other disturbed habitats to optimize travel and foraging

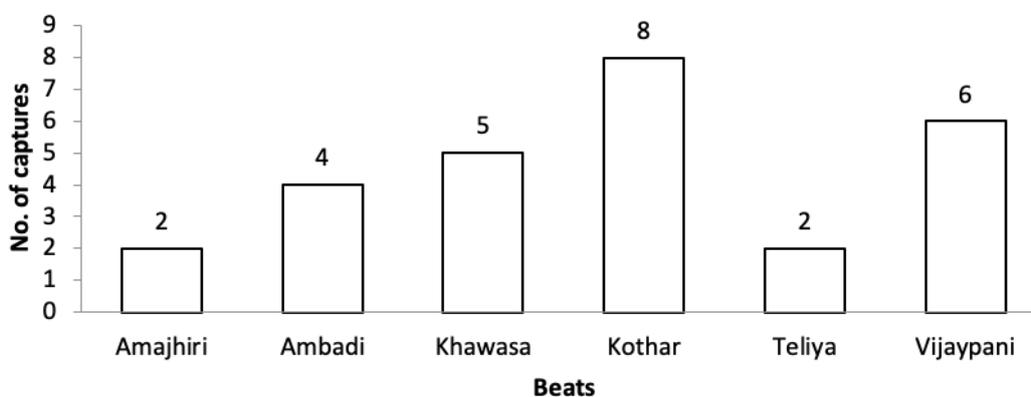


Figure 2. Beat-wise number of captures of the Indian Grey Wolf in the Khawasa range of Pench Tiger Reserve.

Table 2. Habitat-wise tree and shrub indices and counts of wolf evidence in Pench Tiger Reserve.

Habitat	Tree diversity	Tree richness	Tree evenness	Shrub diversity	Shrub richness	Shrub evenness	Wolf evidence
Mixed	2.84	4.345	0.5351	0.811	1.957	0.5144	32
Teak	1.687	3.049	0.2843	0.8107	2.213	0.654	4
Teak Mixed	2.02	3.717	0.3428	0.5522	0.9128	0.5508	4

Table 3. Availability and expected proportional usage with 95% Bonferroni confidence intervals.

Habitat	Observed usage	Expected usage	Actual proportional use (Pi)	Expected proportional use (Pio)	Bonferroni confidence interval	Remark
Mixed	32	26.96	0.8	0.67	$0.654 \leq Pi \leq 0.945$	0
Teak	4	10.02	0.1	0.25	$-0.009 \leq Pi \leq 0.209$	-
Teak mixed	4	3.005	0.1	0.07	$-0.009 \leq Pi \leq 0.209$	0

—Avoided | +—Preferred | 0—used in accordance to availability.

efficiency (Whittington et al. 2005; Houle et al. 2010). Therefore, the observed relationship may reflect a functional response of wolves to human-mediated habitat changes, demonstrating their adaptability in human-dominated landscapes.

Study findings highlight that buffer zones are not merely peripheral spaces but serve as critical habitats for many wildlife species, including wolves. These areas must be recognized for their ecological value and managed accordingly. An effective conservation strategy should integrate habitat management, scientific research, and active community participation to ensure the protection of wildlife across the landscape. To ensure the long-term conservation of wolves in the region, it is essential to adopt a landscape-level conservation approach. Given that wolf packs require large home ranges, ranging 150–300 km² (Jhala 2003; Habib 2007), focusing solely on small habitat patches is insufficient. Conservation efforts should prioritize the protection of natural habitat features and the maintenance of wildlife corridors, enabling free movement between areas and promoting population connectivity (Sharma et al. 2019; Gubbi et al. 2020).

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