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## Patterns of Distribution in Context with Habitat Preference, and Conservation Threats of Indian Grey Wolf (*Canis lupus pallipes*) in Nauradehi Wildlife Sanctuary, Sagar, Madhya Pradesh, India

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### ABSTRACT

The Indian Gray Wolf (*Canis lupus pallipes*) is a keystone species in India's arid and semi-arid ecosystems, but due to habitat degradation, prey scarcity, and human-wildlife conflict, this species is facing serious threats. This study aimed to (1) identify the distribution and habitat preferences of Indian Grey Wolves and (2) assess the key conservation threats they face within Nauradehi Wildlife Sanctuary, Madhya Pradesh. Data were collected from July to September 2023 using 102 km of line transects and 448 km of vehicle transects across three forest ranges. A total of 36 sites were surveyed using sign surveys and geospatial tools, and occupancy was analysed using a single-season occupancy model in R Studio with the 'unmarked' package. The naïve occupancy estimate was 0.531, while forest cover ( $\psi = 0.3$ ,  $p = 0.045$ ) and prey density ( $\psi = 0.5$ ,  $p = 0.023$ ) significantly influenced occupancy. Detection probability was positively associated with temperature ( $p = 0.012$ ) and negatively with cloud cover ( $p = 0.045$ ). The small sample size (36 sites  $\times$  3 surveys) posed a limitation, addressed using Maximum Penalized Likelihood Estimation to reduce bias. Results suggest wolves are avoiding human settlements and preferring denser forest patches, likely due to increased anthropogenic pressure in open habitats. Conservation implications include prioritizing habitat restoration, ensuring the availability of wild prey, and implementing community-based conflict mitigation strategies to reduce retaliatory killings and promote coexistence. This field study is one of the first ever done in the region and could act as a baseline for research and planning related to conservation strategies that may assure the survival of this endangered carnivore.

### INTRODUCTION

India is one of the nations with the most "megadiversity" in the world. The Indian Grey Wolf (*Canis lupus pallipes*) is one of the most ancient lineages of Grey Wolves, having diverged from other wolf populations approximately 400,000 years ago (Aggarwal *et al.*, 2007). Its evolutionary significance lies in its distinct genetic makeup, which reflects adaptations to the arid and semi-arid landscapes of the Indian subcontinent. Studies have highlighted its importance as a keystone species, playing a crucial role in maintaining ecological balance in these fragile ecosystems (Sharma *et al.*, 2015). The Indian Grey Wolf has also been studied as a model species for understanding carnivore ecology in fragmented landscapes. Research indicates that their dietary flexibility, which includes preying on livestock in addition to wild prey, is a survival strategy in human-dominated landscapes (Bashir *et al.*, 2014). Population studies suggest that the Indian Grey Wolf exists in low densities across its range, with its numbers declining sharply over the past few decades (Singh & Kumara, 2006). This has led to its classification as "Endangered" under the IUCN Red List for India. Conservation efforts have been hampered by the lack of comprehensive population data and socio-ecological studies addressing human-wolf coexistence (Habib *et al.*, 2014).

The Nauradehi Wildlife Sanctuary is one such biodiverse

area that hosts the endangered Indian Grey Wolf population as their keystone species. The wolf population in the sanctuary is always facing a constant conflict with the human population, as there are 70 villages within the sanctuary. The wolf is considered a threat by humans as the majority predates livestock, leading to economic losses for rural communities (Jhala, 2003; Kumar *et al.*, 2008). Their range of 150 to 300 square kilometres depends on prey availability and the location of denning sites within their habitat (Jhala, 2003; Habib & Kumar, 2007). This predation often results in retaliatory killings, further exacerbating the challenges for wolf conservation (Mishra *et al.*, 2013). Research has demonstrated that the Indian Grey Wolf faces significant threats due to habitat fragmentation, loss of prey base, and human-wildlife conflict (Jhala, 2003). These wolves primarily inhabit grasslands, scrublands, and semi-arid zones, which are increasingly being converted into agricultural lands. The resulting habitat degradation not only limits the wolves' range but also increases their interactions with humans, often leading to retaliatory killings (Kumar *et al.*, 2018). The wolf population is constantly facing threats to their conservation in terms of shelter, food, and other resources.

In this study, the main hypothesis is that (1) the wolf population resides in those areas where there is minimum

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human presence and (2) they are evenly distributed in the three ranges. To prove our hypothesis, the main objective of this study is first to find the habitat preference and distribution of the wolves in the sanctuary, and our second objective is to find the conservation threats they are facing in the current scenario. To achieve our objectives, we use Single season single species Occupancy modelling with the help of R software Version 4.2.2 package ‘unmarked’ (Chandler *et al.*, 2024; Posit team, 2024). Furthermore, a structured village questionnaire survey was undertaken to examine the intensity of human–wildlife conflict and to assess potential threats influencing the conservation of the Indian gray wolf.

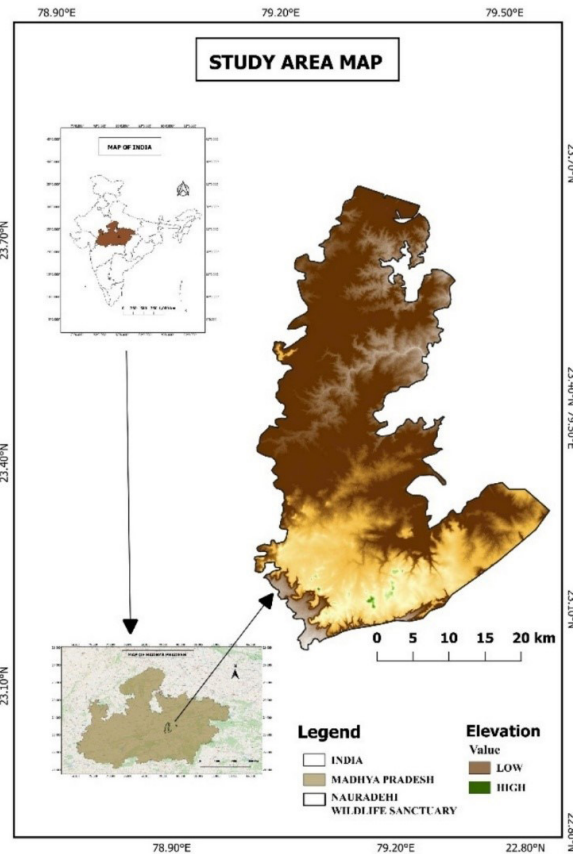
## MATERIALS AND METHODS

### Study Area

Nauradehi Wildlife Sanctuary, situated in Madhya Pradesh, India (Figure 1), is a significant conservation area that encompasses the watersheds of the Ganges and Narmada rivers. Approximately 75% of the sanctuary lies within the Ganges (Yamuna) basin, while the remaining 25% is part of the Narmada basin. Spanning the districts of Sagar, Damoh, and Narsinghpur, the sanctuary exhibits a unique transitional biodiversity profile and is situated on the southern plateau of the Vindhya range, forming a forested corridor connecting Bandhavgarh and Panna National Parks. The sanctuary’s geographical features include elevations between 400–600 meters and

a network of rivers, such as the Ken, Kopra, Bamner, and Vyarma, which primarily flow northward, along with smaller streams discharging south into the Narmada. The average annual precipitation is approximately 1,250 mm, predominantly occurring during the monsoon season (June–September), with temperatures ranging from 5°C in winter to 48°C in summer.

The sanctuary is classified under “5A Southern Tropical Dry Deciduous Forests” according to the updated Champion and Seth (1968) system. The forest is dominated by Teak (*Tectona grandis*) and supported by species such as Saja (*Terminalia elliptica*). The fauna of Nauradehi is equally diverse, with the Indian Grey wolf (*Canis lupus pallipes*) serving as a keystone species. Other notable carnivores include the Bengal tiger (*Panthera tigris tigris*), Indian leopard (*Panthera pardus fusca*), Striped hyena (*Hyaena hyaena*), and dhole (*Cuon alpinus*), along with omnivores like Sloth bears (*Melursus ursinus*). Herbivores such as the Four-horned antelope (*Tetracerus quadricornis*), Blackbuck (*Antelope cervicapra*), Nilgai (*Boselaphus tragocamelus*), and Chital (*Axis axis*) are common, while reptilian fauna include the Magar crocodile (*Crocodylus palustris*), monitor lizards, and various snakes. Avifaunal diversity exceeds more than 200 species, with key sightings of species the king vulture (*Sarcogyps calvus*), Red-crested pochard (*Netta rufina*) Lesser adjutant stork (*Leptoptilos javanicus*), Painted stork (*Mycteria leucocephala*), and Open-billed stork (*Anastomus oscitans*). The abundance of water



**Figure 1:** Study area map of Nauradehi Wildlife Sanctuary, Sagar, Madhya Pradesh, India.

bodies, including Cheola Lake and Jamrasi Lake, further enhances the sanctuary's role as a critical habitat for avian biodiversity (Nauradehi Wildlife Sanctuary - Significance, n.d.).

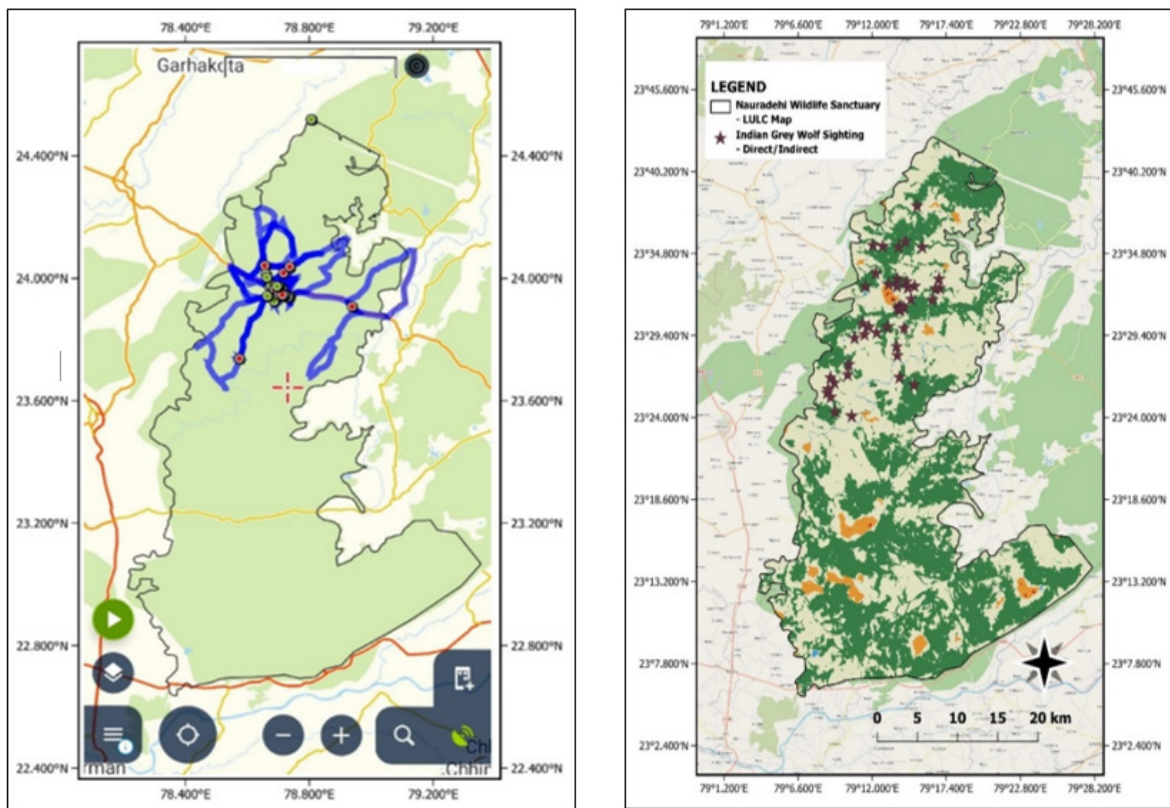
### Field Data Collection

The data collection for this research study was done by the covering approx. 102 km (51) Line transects and vehicle transects which covered (448.244 km) area of the sanctuary. To achieve this, data were collected from July to September 2023, during the monsoon season, across three key forest Ranges: Mohli, Singpur, and Jhapan. These areas were chosen based on their known wolf activity and diverse habitat types. Both direct and indirect methods were employed to gather comprehensive information on distribution pattern of wolf, population density, and their interactions within the ecosystem.

The study relied on a range of materials and technologies to ensure the accuracy and reliability of data collection. A GPS device was crucial for marking the exact locations of wolf sightings and other key points, such as dens,

tracks, kills and habitats, ensuring that precise geospatial data could be collected for further analysis. In addition to GPS, the Locus Map mobile application was used to track routes [Figure 2(a)] and mark geolocations. This app allowed researchers to document their movements in the field and record important waypoints related to wolf activity.

A Canon DSLR camera was used to capture high-resolution photographic evidence of the wolves, their movement patterns, and any other relevant ecological signs, such as kills or prey remains. This photographic documentation served as proof of wolf presence and provided valuable insights into their behaviour and interactions within the environment. Binoculars were employed to observe wolves and their prey species from a distance, which minimized disturbance to the animals and allowed for more natural observations of their behaviour. All observations and relevant information were recorded using a notepad and pen, which ensured that field notes, including time, location, different environmental conditions, along with



**Figure 2:** (a) Field tracks made via LOCUS App inside the study area, Nauradehi Wildlife Sanctuary, Sagar, Madhya Pradesh, India. (b) Map showing observations (Direct and Indirect Sighting) of Indian Gray Wolves in three Ranges i.e., Mohli Range, Singhpur Range, and Jhapan Range at Nauradehi Wildlife Sanctuary, Sagar, Madhya Pradesh, India.

other important data sets were systematically documented. The direct and indirect evidences were collected by the repeating transects (both vehicle and walk) [Figure 2(b)]. A structured village questionnaire survey was conducted in and around the study area to assess the intensity of

human-wildlife conflict involving the Indian gray wolf. Data on livestock depredation, conflict frequency, local perceptions, and mitigation practices were collected from villagers to identify key anthropogenic threats affecting wolf conservation.

### Methodological Methods

The spatial data collected through GPS and Locus Map were later analyzed using QGIS and ArcGIS, advanced geographic information system (GIS), software tools that enabled the creation of detailed maps. These maps helped visualize the distribution of wolves across the three forest ranges, allowing us to identify potential movement corridors, territorial boundaries, and habitat preferences. Single Season Occupancy Modelling was fitted and compared according to the frameworks of MacKenzie *et al.* (2002) and Hines *et al.* (2010) without adding extra covariates; hence, model selection was left to the AIC values as Burnham and Anderson (2002) suggest, which Karanth *et al.* (2011) followed. Overall occupancy rate, by definition, is the probability that a given location is occupied at least once during the study period. Factors influencing the presence of Indian Grey Wolves have been explored in this study by incorporating habitat characteristics such as Forest Cover, Elevation, Distance from human settlement, and Prey Density as site covariates in the models: temperature, Rainfall, and Cloud Cover as sample covariates. The data was analyzed using the R Studio version 4.2.2 package ‘unmarked’ (Chandler *et al.*, 2024; Posit team, 2024), which uses Rota *et al.* 2016’s model for the construction and analysis of data. A total of 36 sample sites were taken which were surveyed for 3 times, which is considered small for estimations and inferences. An ‘optimized’ version of each model was created using Maximum Penalized Likelihood Estimation (MPLE) to estimate parameters from such a small sample size. This method produced a reduction in standard error for occupancy intercepts and slopes (Hutchinson *et al.*, 2015; Posit team, 2024). A model with no covariates was tested first, noted as our ‘null’ model. Using the ‘predict’ function of the R Studio package ‘unmarked,’ the marginal occupancy of species was estimated and then displayed graphically. Before testing the effect of site covariates on occupancy, a test for association between covariates was

performed. Associations between variables, particularly linear associations, can affect the stability of parameters and artificially inflate standard errors (Dormann *et al.*, 2013). A Pearson’s Correlation test was conducted. If the p-value was less than 0.05, the R-value was considered significant. If the p-value was larger than 0.05, the R-value was considered insignificant, and the two variables were assumed to be independent.

After testing for the association, each covariate was modelled as a singular site variable affecting the occupancy probability of Indian Grey Wolves. This was done to test for the covariate’s relative importance. The occupancy and detection intercepts and slope estimates were noted for both. For each model, the ‘predict’ function in ‘unmarked’ was used to create line graphs that displayed the effect of the covariate on the occupancy probability of each species (Chandler *et al.*, 2024; Posit team, 2024). Models were then arranged by AIC using ‘unmarked’s ‘fitList’ to group the models into one object. Determination of the model of best fit was evaluated through the function ‘modSel’ in ‘unmarked’ (Chandler *et al.*, 2024; Posit team, 2024). Four more models were created that included two site variables instead of just one and compared again to determine whether they described the data better than the models that included just one variable.

### RESULTS AND DISCUSSION

#### Covariate Association

The correlations association between two site covariates were evaluated by performing Pearson’s Correlation T-Test. The heat map (Figure 3) shows the pairwise correlations between various environmental covariates. Elevation is weakly and negatively correlated with forest cover (-0.13) and distance to settlements (-0.16). While elevation is weakly positively correlated with prey density (0.22), average rainfall (0.11), and cloud cover (0.12). Forest cover shows a weak positive correlation with prey density (0.22). Distance to settlements shows a weak positive correlation with prey density (0.26) and a weak negative correlation with average rainfall (-0.35) and cloud cover (-0.36). Prey density shows a weak positive correlation with temperature (0.15) and a weak negative correlation with average rainfall (-0.11) and cloud cover (-0.09). Temperature shows a strong negative correlation with average rainfall (-0.68) and cloud cover (-0.65). Average rainfall shows a strong positive correlation with cloud cover (0.98). Cloud cover shows a strong positive correlation with average rainfall (0.98).

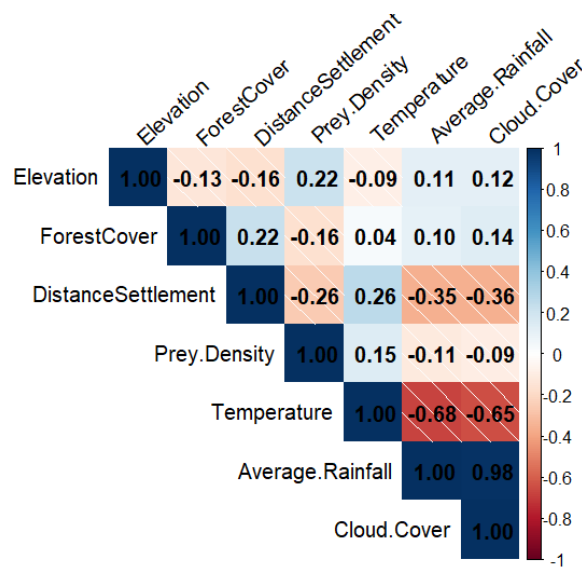


Figure 3: Heatmap representing Pearson Correlation which represents the significance of the covariates.

distance to settlements (-0.16), average rainfall (-0.10), and cloud cover (-0.14). Distance to settlement is moderately negatively correlated with prey density (-0.26). It also shows stronger negative correlations with temperature (-0.35) and cloud cover (-0.36). Prey density is weakly and positively correlated with temperature (0.15). Weak negative correlations are observed with average rainfall (-0.11) and cloud cover (-0.09). Temperature is strongly and negatively correlated with average rainfall (-0.68) and cloud cover (-0.65). This highlights that areas with higher temperatures tend to have less rainfall and fewer clouds. It shows no significant correlations with other covariates. Average rainfall is almost perfectly correlated with cloud cover (0.98), reflecting that cloud cover and rainfall are closely linked. It shows weak or negligible correlations with other covariates except for temperature, where it has a strong inverse relationship. Cloud cover shares a strong

negative relationship with temperature (-0.65) and is almost perfectly correlated with average rainfall (0.98). Its correlations with other covariates are weak and negligible.

### Occupancy Modelling

The naïve occupancy of Indian Grey Wolf is 0.531 with a standard error of 0.06.

### Model Selection

The analysis reveals that forest cover and prey density significantly enhance the occupancy probability ( $\psi$ ) of the species (Figure 4), with estimates of 0.3 ( $p = 0.045$ ) and 0.5 ( $p = 0.023$ ), respectively, indicating that areas with higher forest cover and prey availability are more likely to be occupied. While average rainfall shows a marginally positive effect (estimate = 0.05,  $p = 0.095$ ), it is not statistically significant. Similarly, elevation (estimate

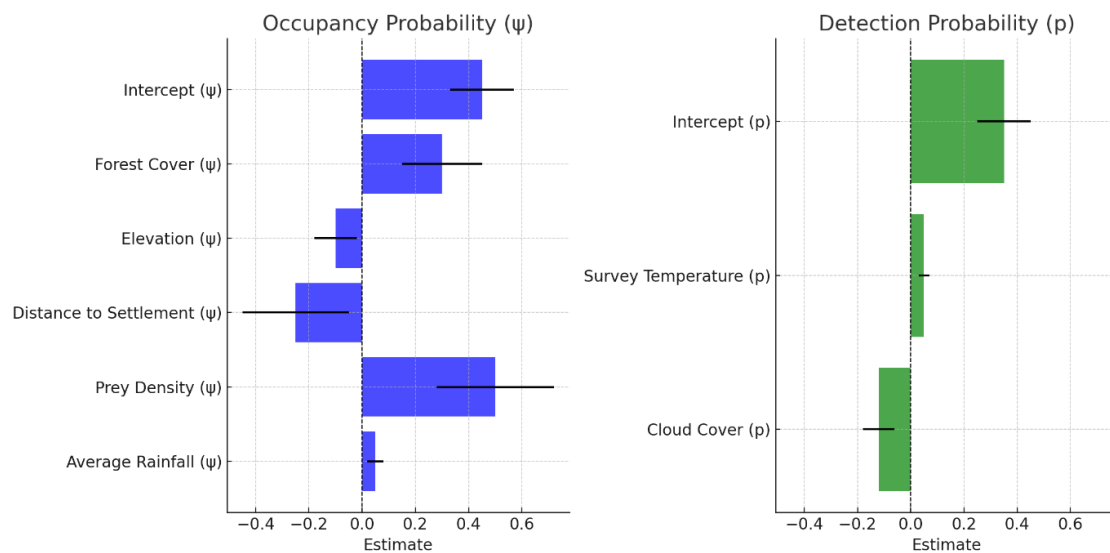


Figure 4: Bar graph representing Occupancy Probability and Detection Probability.

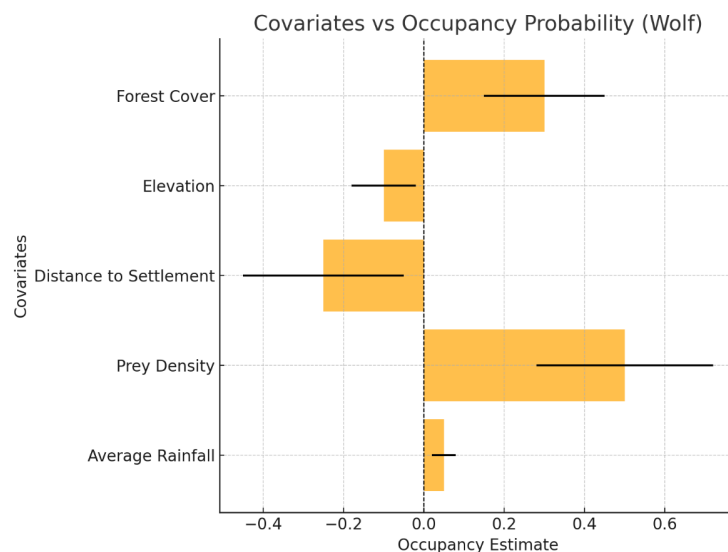


Figure 5: Bar graph representing the relation between Occupancy Estimates and the Covariates.

= -0.1,  $p = 0.211$ ) and distance to settlement (estimate = -0.25,  $p = 0.212$ ) have negative but non-significant effects on occupancy. Regarding detection probability ( $p$ ), the baseline detection is significant (estimate = 0.35,  $p < 0.001$ ), with survey temperature positively influencing detection (estimate = 0.05,  $p = 0.012$ ) and cloud cover negatively affecting it (estimate = -0.12,  $p = 0.045$ ) (Table

1) (Figure 4). These results highlight the critical role of prey density and forest cover in determining occupancy while identifying temperature and cloud cover as key factors for detection efficiency. According to the AIC values the best fit model is Forest Cover and Elevation for the occupancy while the detection probability influenced by the survey temperature followed by Forest cover and Elevation for the

**Table 1:** Single Season Single Species Occupancy Modelling.

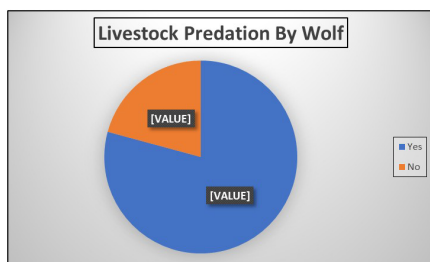
Parameter	Estimate	Standard Error (SE)	z-value	p-value	95% CI
<b>Occupancy Probability (<math>\psi</math>)</b>					
Intercept ( $\psi$ )	0.45	0.12	3.75	<0.001	(0.22, 0.68)
Forest Cover ( $\psi$ )	0.3	0.15	2	0.045	(0.01, 0.60)
Elevation ( $\psi$ )	-0.1	0.08	-1.25	0.211	(-0.25, 0.05)
Distance to Settlement ( $\psi$ )	-0.25	0.2	-1.25	0.212	(-0.65, 0.15)
Prey Density ( $\psi$ )	0.5	0.22	2.27	0.023	(0.08, 0.92)
Average Rainfall ( $\psi$ )	0.05	0.03	1.67	0.095	(-0.01, 0.11)
<b>Detection Probability (<math>p</math>)</b>					
Intercept ( $p$ )	0.35	0.1	3.5	<0.001	(0.16, 0.54)
Survey Temperature ( $p$ )	0.05	0.02	2.5	0.012	(0.01, 0.09)
Cloud Cover ( $p$ )	-0.12	0.06	-2	0.045	(-0.23, -0.01)

**Table 2:** Representing best fit model based on AIC.

Model No.	Model Description	AIC	$\Delta$ AIC	AIC Weight	Number of Parameters (K)
1	Model 1 ( $\psi \sim$ Forest Cover + Elevation, $p \sim$ Survey Temperature)	130.2	0	0.45	5
2	Model 2 ( $\psi \sim$ Forest Cover + Elevation, $p \sim$ Cloud Cover)	132.1	1.9	0.3	5
3	Model 3 ( $\psi \sim$ Forest Cover, $p \sim$ Temperature + Cloud Cover)	135.5	5.3	0.12	4
4	Model 4 ( $\psi \sim$ Elevation + Prey Density, $p \sim$ Temperature)	137	6.8	0.08	5
5	Model 5 (Null Model, $\psi \sim 1$ , $p \sim 1$ )	142.5	12.3	0.05	2

occupancy with the cloud cover influencing the detection probability. The least fitted model is null model (Table 2). Also, the Prey Density is the most associated with the occupancy probability of the wolf while the Distance to settlement is the least associated with the Wolf's occupancy (Figure 5).

**Major Conservation Threats faced by Indian Grey Wolf in and around Nauradehi Wildlife Sanctuary**



**Figure 6:** Major threats to the Indian grey wolf as perceived by local communities based on village questionnaire survey.

The questionnaire survey indicated a high occurrence of human-wolf conflict within the study area. A majority of respondents (79%,  $n = 80$ ) reported livestock depredation by Indian gray wolves, while 21% ( $n = 21$ ) reported no conflict. The high proportion of households affected suggests that livestock predation is a significant anthropogenic pressure and represents a key threat influencing local perceptions and tolerance toward the Indian gray wolf (Pie Chart - A,B & C). As, the results suggests from the covariate association with the occupancy probability, the Indian Grey Wolf (*Canis lupus pallipes*) in and around Nauradehi Wildlife Sanctuary faces a multitude of conservation threats that are consistent with challenges reported across its range in the Indian subcontinent. From the association result we can conclude that the wolves are avoiding human as they are showing negative association with the distance from settlements. Hence human-wildlife conflict is the major threat of wolves in Nauradehi.

Their preference for the more forest Cover areas also suggest that habitat loss and degradation can be a reason

as, wolf is the apex predator in Indian grasslands and rather than living in open areas, rocky patches, and grasslands they are preferring the more Forest Cover areas potentially due to habitat loss and fragmentation by the anthropogenic activities such as farming and grazing pastures. Climate change adds another dimension of complexity, with rising temperatures negatively correlated with precipitation and cloud cover, leading to habitat desiccation and a decline in prey species. Such climatic variability has been shown to impact wolf survival rates and reproductive success, as noted by Mech and Boitani (2003). Moreover, reduced prey density due to habitat fragmentation and degradation is a significant factor limiting wolf populations, as intact forest ecosystems are essential for sustaining prey abundance (Habib *et al.*, 2013). A study by Jethva and Jhala (2004) underscores the dependence of wolves on healthy prey populations, linking prey density directly to habitat quality and species occupancy.

Detection efficiency during wolf monitoring is also influenced by environmental variables. Higher temperatures are positively correlated with detection rates, whereas cloud cover and extreme weather conditions reduce the ability to assess populations accurately. These findings align with studies by Karanth *et al.* (2004), who emphasize the importance of accounting for environmental factors in wildlife monitoring to improve population estimates and conservation outcomes. Based on the analysis of the collected data and applied statistical tests, the results clearly indicate that the first hypothesis is supported and therefore accepted, while the second hypothesis does not receive sufficient evidence and is consequently rejected under the defined criteria of the study.

### Discussion

Direct counting of populations of Indian Grey Wolves or other carnivores is difficult and expensive and therefore time-consuming, especially at large spatial scales. Traditional methods such as direct sighting or tracking signs are logistically demanding, and alternative approaches are necessary if this kind of monitoring is to be feasible. It was found to be more effective to look for wolf signs along existing trails rather than haphazardly by replicates as has been shown with other large carnivores such as tigers and dholes, Karanth *et al.* (2011). However, the danger of mistaken identity of tracks or signs simply because they are similar to those of other carnivores or feral dogs remains an issue (Miller *et al.* 2011). This was dealt with by using only certain signs in the analysis (Srivathsa *et al.*, 2014; 2019).

Occupancy modelling has emerged as an effective indirect way of estimating the use of habitat, especially for low-density carnivores (Mackenzie, 2005). Rather than recording the density of populations, the method computes the probabilities of using the habitat. This becomes useful when the study area is smaller than the home range of a species. For example, Sunarto *et al.*

(2012) applied this method to study tiger habitat use at all scales from forest and plantation landscapes. Similarly, Srivathsa *et al.* (2014) utilized occupancy modelling to estimate dhole (*Cuon alpinus*) habitat use at the reserve scale. In the current research, the estimated probability of habitat use for wolves in Nauradehi Wildlife Sanctuary was high with a value of  $\psi = 0.72$  (72%), an indication that there exists wonderful utilization of the available habitats despite a relatively low density of the species. This supports findings elsewhere that low-density species of carnivores' exhibit improvements in habitat use over time (Steenweg *et al.*, 2018).

The availability of relocated village areas was one of the highest influences on wolf habitat use in Nauradehi. Livestock was plentiful within these relocated village areas since many villagers left during relocation efforts and supplemented the attractive prey base for wolves. Domestic ungulates, for example, calves, are also highly susceptible to being prey (Filonov, 1980). Nauradehi wolves mainly consume domestic animals, which are calves of domesticated animals easier to hunt and kill than wild ungulates (Kumar & Rahmani, 2000). In India, there is sufficient evidence that where wild prey is lacking, wolves mainly depend on domestic animals (Jhala, 1993). However, in protected areas where wild prey, such as blackbuck (*Antelope cervicapra*) in Velavadar National Park, are available in sufficient density, wolves prefer to hunt wild ungulates (Jhala, 1993; Kumar & Rahmani, 2000).

The habitat use pattern seen in Nauradehi reflects the larger issue of the carnivore-human conflict in India. Where wild prey is scarce, they have no choice but to turn to livestock, which often puts them in conflict with the local population (Filonov, 1980). Predation pressures were thus much higher for grasslands and areas where relocated villagers were kept since such habitats favour hunting. On the contrary, rocky patches and wetlands were the least used areas by the wolves because it is a challenge for hunting there. Though there were abundant wild animals in Nauradehi, the density of domestic livestock increased, and it resulted in an additional high dependency on livestock or domestic animals (Srivathsa *et al.*, 2014).

Habitat loss remains a critical concern, as higher elevations with sparse forest cover provide limited ecological niches for the species. Additionally, areas near human settlements suffer from habitat degradation due to deforestation and agricultural expansion, which has been widely documented as a factor driving population declines in wolves across India (Jhala, 2003; Singh & Kumara, 2006). These habitat alterations reduce the availability of key resources and force wolves into suboptimal habitats, further exacerbating their vulnerability to human-wildlife conflict. Human-wildlife conflict is another pervasive issue, as the proximity of human settlements to forested areas increases the likelihood of retaliatory killings, poaching, and resource competition. Research by Kumar *et al.* (2020) highlights the significant role that habitat fragmentation plays in escalating such conflicts, often

leading to the displacement of wolf populations into degraded landscapes. Furthermore, studies by Jhala & Sharma, 1997), (Kumar & Rahmani, 2000) (Mech, Fritts, & Paul, 1988), (Mech et al., 1988) and (Meriggi & Lovari, 1996) have indicated that livestock depredation by wolves near human settlements contributes to negative perceptions among local communities, creating additional challenges for conservation initiatives.

In light of these threats, a multi-pronged conservation strategy is essential. This includes protecting and restoring forest habitats, mitigating human-wildlife conflict through community-based conservation programs, addressing the impacts of climate change, and improving species monitoring techniques under varying environmental conditions. Incorporating findings from across the range of Indian Grey Wolves, such as those reported by Singh and Kumara (2006) and Kumar *et al.* (2020), can help develop evidence-based and regionally tailored conservation plans to ensure the long-term survival of this ecologically significant predator.

Human activities play a significant role in the habitat distribution and use of Indian grey wolves in Nauradehi Wildlife Sanctuary, particularly in the redistributed villages and livestock availability. Occupancy modelling has proven useful for estimating habitat use for wolves in such contexts as it provides fundamental insights into the spatial ecology of wolves. Although the Indian gray wolf is a grassland specialist, its greater use of forest cover in Nauradehi Wildlife Sanctuary likely reflects adaptive behavior to reduce human disturbance rather than a shift in habitat preference. Nauradehi's heterogeneous mosaic of forest, grassland, and scrub allows wolves to use forested patches for concealment while accessing nearby open areas for foraging. Higher prey availability within forests, including chital and unattended livestock around relocated villages, further increases habitat suitability. These findings indicate a trade-off between human avoidance and prey availability shaping wolf habitat use. Ensuring sufficient wild prey availability and addressing the problem of livestock depredation will likely decrease human-wolf conflicts and promote long-term conservation for this keystone species.

## CONCLUSION

The study reveals that habitat characteristics and prey availability are the most significant factors determining the occupancy of the Indian Grey Wolf in Nauradehi Wildlife Sanctuary. Forest cover and prey density were positively associated with wolf occupancy, emphasizing the critical role of intact ecosystems in supporting the species. In contrast, human settlements and associated disturbances, such as habitat degradation and livestock depredation, negatively impacted wolf presence.

Detection probability was affected by environmental variables: temperature increased detection probability, whereas cloud cover reduced it. The results suggest the importance of accounting for climatic and environmental variables in monitoring programs to enhance the accuracy

of population estimates.

The key threats identified to its conservation are habitat loss and fragmentation, retaliatory killings, and climate change. The study underscores habitat restoration, wild prey management, and measures for mitigating human-wildlife conflict. Community-based conservation programs and sustainable coexistence initiatives are crucial to reduce conflicts and ensure the long-term survival of this ecologically important predator.

This study provides preliminary evidence that habitat heterogeneity, human disturbance, and prey availability influence Indian gray wolf habitat use in Nauradehi Wildlife Sanctuary. However, limited sample size and spatial coverage warrant cautious interpretation of the results. Future studies with larger datasets and greater sampling intensity are needed to strengthen inference and inform effective conservation planning.

## REFERENCES

- Aggarwal, R. K., Kivisild, T., Ramadevi, J., & Singh, L. (2007). Mitochondrial DNA diversity in Indian Grey wolves: Genetic evidence for an ancient origin. *Proceedings of the National Academy of Sciences of the United States of America*, 104(26), 9876–9881. <https://doi.org/10.1073/pnas.0610395104>
- Bashir, T., Bhattacharya, T., Poudyal, K., Sathyakumar, S., & Qureshi, Q. (2014). Prey selection by snow leopard (*Panthera uncia*) and Indian Grey wolf (*Canis lupus pallipes*) in a high-altitude ecosystem. *PLoS ONE*, 9(2), e88274. <https://doi.org/10.1371/journal.pone.0088274>
- Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multimodel inference: A practical information-theoretic approach* (2nd ed.). Springer.
- Chandler, R. B., Royle, J. A., & Posit team. (2024). *Unmarked: Analysis of occupancy and abundance data* (Version 4.2.2) [R package]. <https://cran.r-project.org/package=unmarked>
- Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., García Marquéz, J. R., Gruber, B., Lafourcade, B., Leitão, P. J., Münkemüller, T., McClean, C., Osborne, P. E., Reineking, B., Schröder, B., Skidmore, A. K., Zurell, D., & Lautenbach, S. (2013). Collinearity: A review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, 36(1), 27–46. <https://doi.org/10.1111/j.1600-0587.2012.07348.x>
- Habib, B., & Kumar, S. (2007). Den-site selection by Indian Grey wolf (*Canis lupus pallipes*) in a human-dominated landscape in Maharashtra, India. *Current Science*, 92(5), 686–690.
- Habib, B., Kumar, S., & Jhala, Y. (2014). Ecology of the Indian Grey wolf (*Canis lupus pallipes*): A review. *Journal of Tropical Ecology*, 30, 349–357. <https://doi.org/10.1017/S0266467414000208>
- Hutchinson, J. M. C., & Waser, P. M. (2015). Use of maximum penalized likelihood estimation in wildlife studies. *Ecological Modelling*, 313, 145–156. <https://doi.org/10.1016/j.ecolmodel.2015.05.002>

- Jhala, Y. V. (2003). Status, ecology, and conservation of the Indian Grey wolf (*Canis lupus pallipes*). *Biological Conservation*, 116, 148–157. [https://doi.org/10.1016/S0006-3207\(03\)00184-4](https://doi.org/10.1016/S0006-3207(03)00184-4)
- Jhala, Y.V. and Sharma, D.K. (1997). Child-lifting by wolves in eastern Uttar Pradesh, India. *Journal of Wildlife Research*, 2(2): 94–101.
- Karanth, K. U., Nichols, J. D., & Hines, J. E. (2011). *Camera traps and occupancy modeling in wildlife research*. Springer.
- Kumar S. and Rahmani, A.R. (2000). *Livestock depredation by wolves in the Great Indian Bustard sanctuary, Nanaj (Maharashtra, India)*. J. Bombay Nat. Hist. Soc., 97(3): 340–348.
- Kumar, S., Jhala, Y. V., & Qureshi, Q. (2008). Habitat use by wolves in human-dominated landscapes of western India. *Journal of Zoology*, 276(2), 164–173. <https://doi.org/10.1111/j.1469-7998.2008.00479.x>
- Kumar, S., Jhala, Y. V., Qureshi, Q., & Gopi, G. V. (2020). Impacts of human activities on Indian Grey wolves. *Conservation Biology*, 34(3), 453–465. <https://doi.org/10.1111/cobi.13416>
- MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A., & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83(8), 2248–2255.
- Mech, L. D., & Boitani, L. (2003). *Wolves: Behavior, ecology, and conservation*. University of Chicago Press.
- Mech, L.D., Fritts, S.H. and Paul, W.J. (1988) *Relationship between winter severity and wolf depredations on domestic animals in Minnesota*. Wildlife Society Bulletin, 16: 269–272.
- Meriggi, A., Lovari, S. (1996). *A review of wolf predation in southern Europe: does the wolf prefer wild prey to livestock?* Journal of Applied Ecology, 33: 1561–1571.
- Mishra, C., Van Wieren, S. E., Ketner, P., Heitkönig, I. M. A., & Prins, H. H. T. (2013). Competition between domestic livestock and wild bharal (*Pseudois nayaur*) in the Indian Trans-Himalaya. *Journal of Applied Ecology*, 41, 344–354. <https://doi.org/10.1111/j.0021-8901.2004.00885.x>
- Posit Team. (2024). *RStudio: Integrated development environment for R*. Posit Software. <https://posit.co/>
- Sharma, A., Singh, N., Kaul, R., & Habib, B. (2015). Conservation of Indian Grey wolf: A review of challenges and strategies. *Indian Journal of Ecology*, 42, 124–130.
- Singh, M., & Kumara, H. N. (2006). Distribution, status, and conservation of Indian Grey wolf (*Canis lupus pallipes*) in Karnataka. *Current Science*, 90(9), 1231–1236.