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Research report

Preliminary status of the Indian grey wolf in Kailadevi Wildlife Sanctuary, Rajasthan, India

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Abstract

The Indian grey wolf (*Canis lupus pallipes*) is the apex predator of the semi-arid landscapes of India. They have large home ranges and mostly thrive outside the protected areas, feeding on livestock to fulfil dietary needs, thus bringing them into direct conflict with humans, making it imperative to identify and conserve wolf-occupied areas. We used questionnaire surveys and field methods to estimate the number and status of wolves in Kailadevi Wildlife Sanctuary, Rajasthan. We estimated 19 – 45 wolves occurring at a density of 0.02 – 0.06 wolves/km^2 in 672.82 km^2 of Kailadevi Wildlife Sanctuary. The maximum number was estimated from the Nainyaki range. The presence of wolves was significantly positively related to the presence of sheep and goats. Due to low availability of natural prey in the study area, wolves depend on livestock, causing high economic loss to the resident people. Our study suggests that if strict conservation measures are taken, Kailadevi Wildlife Sanctuary holds the potential to act as a source population for the conservation of the Indian grey wolf in the larger landscape surrounding the study area. However, due to high anthropogenic pressure, the landscape is severely degraded and requires immediate attention to restore the existing scrubland for denning and rendezvous sites. Effective compensation schemes and awareness through outreach and education are required to reduce negative attitudes among the resident people and to prevent wolf persecution. Future research should make use of modern radio-telemetry techniques to better understand the ecology of the wolves in this landscape.

Introduction

The Indian grey wolf (*Canis lupus pallipes*) is an endangered species on Schedule 1 of Indian Wildlife according to the Wildlife (Protection) Act 1972 and is also on Appendix I of CITES for the population of India, Bhutan, and Nepal. The Indian wolf evolved 400,000 years ago, probably during the drier period of the Pleistocene to make use of a relatively unoccupied niche as the apex predator of the arid zones (Jhala 2003, Sharma et al. 2004). The arid and semi-arid regions including the open grasslands, shrub lands, rocky hills, and marginalized agricultural areas form the major habitat of wolves in India (Jhala 2003, Agarwala and Kumar 2009). However, they have also been reported in some forested areas of central India, plains of Terai (Dey et al. 2010), and exceptionally in moist forested habitats of Orissa, Bihar and parts of West Bengal (Shahi 1982, Sharma et al. 2019).

Shahi (1982), in his preliminary survey, estimated the wolf population in India to be around 800 individuals patchily distributed across peninsular India. As of 2003, their population was closer to 2000 – 3000 individuals (Jhala 2003) but there has been no recent study across India to inform the current status of the species. In Gujarat, the estimated population is assumed to be around 190 – 270 and in Rajasthan it is around 253 – 350 (Jhala and Giles 1991). Wolves occur in low densities ranging from 0 – 0.06 wolves/km^2 in Gujarat and Rajasthan. In a 15,017 km^2 area of Solapur in Maharashtra, the estimated population was found to be around 53 – 85 wolves (Kumar and Rahmani 1997) with a density of 0.01 – 0.05 wolves/km^2. Singh & Kumara (2006) estimated a total number of 555 wolves in Karnataka with a density of 0.005 wolves/km^2.

For the conservation and management planning of wide-ranging large carnivores like the Indian wolf, it has often been suggested that Protected Area (PA) networks are inadequate (Singh and Kumara 2006, Sharma et al. 2019). Effective conservation of such species requires landscape level management, but with the average size of a PA in India as small as 240 km^2 (UNEP-WCMC 2021), wide-ranging carnivores are more prone to extinction (Woodroffe and Ginsberg 1998). However, strictly protected areas can provide an opportunity for these species to establish a source population, thereby increasing the probability of connecting dispersing individuals between relatively isolated subpopulations of large carnivores (Pereira et al. 2020). Effectively managed small PAs can act as breeding centres for wolves (Jhala and Giles 1991). Therefore, for effective management of wolves, it is imperative to identify and conserve wolf occupied areas. Our study provides preliminary information on the current status of Indian grey wolves in the Kailadevi Wildlife Sanctuary, Rajasthan, and paves the path for the conservation of the species in the larger landscape.

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Methods

Study Area

Kailadevi Wildlife Sanctuary (KWLS), situated in the Karauli district of the western Indian state of Rajasthan (Figure 1), is a part of the buffer zone of Critical Tiger Habitat (CTH) of Ranthambhore Tiger Reserve (RTR) and covers almost 50% of RTR forming the northern boundary of Ranthambore National Park. The rivers Banas and Chambal form the western and south-eastern boundaries of KWLS, respectively. The sanctuary covers an area of 672.82 km^2 and lies between latitudes 26°13'40.05"N and 26°15'17.42"N and longitudes 76°35'52.68"E and 77°13'52.45"E. The rough terrain of KWLS can be attributed to the Great Boundary Fault formed due to the confluence of the ancient Aravalli and Vindhyan hill systems. The northern extension of the great Vindhyan Plateau is composed of table-top plateaus commonly known as 'Dangs'. Parallel ridges which form deep gorges, locally known as 'Khoh', are another important feature of the local geography. The ridges are separated by dense forests, and some of the gorges are characterized by good soil with a high moisture retention capacity, providing a cool temperature throughout the year. The slopes of the Khoh are covered with dense forest. All these features support a rich floral and faunal diversity in the area.

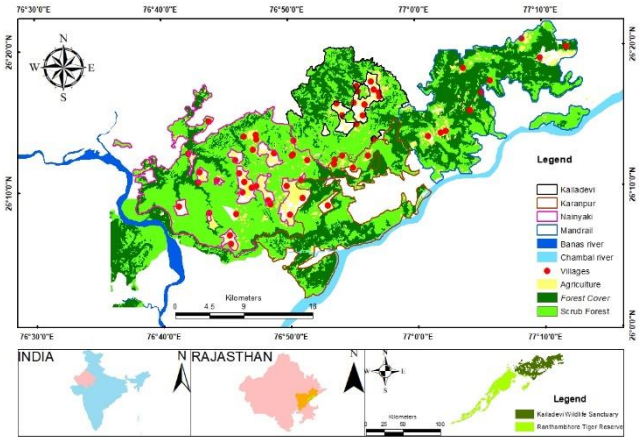

Figure 1 Map of Kailadevi Wildlife Sanctuary, Rajasthan showing the villages inside the sanctuary

The forest composition of KWLS comprises of Northern Tropical Dry Deciduous forests (5B) and subgroup 6B -DS1-Zizyphus scrub, DS1-Dry deciduous scrub and SS4 -Dry Grass lands (Champion and Seth 1968). Dhonk or Anogeissus pendula is the dominant tree species constituting nearly 80% of the vegetation cover. KWLS is home to an array of large mammalian species such as tigers (*Panthera tigris*), leopards (*Panthera pardus*), and sloth bears (*Melursus ursinus*). The sanctuary forms an important buffer area for tigers dispersing from RTR, and currently supports four tigers. It is therefore an important habitat for securing the future of the growing tiger population in RTR. KWLS is rich in faunal biodiversity and supports a number of canid and small felid species. The ungulate species nilgai (*Boselaphus tragocamelus*) and chinkara (*Gazella bennettii*) are present in low density (Jhala et al. 2020).

The sanctuary is inhabited by a number of agro-pastoralist communities of which Gujjar community is predominant, followed by Meena and others. These communities are an integral part of KWLS and derive a substantial part of their livelihood from the forest resources. Villages inside the forest and in its peripheries exert immense biotic pressure on the forest for resources like timber, fodder etc. Due to the large number of livestock holdings, the habitat of KWLS is adversely affected due to overgrazing. Moreover, high numbers of livestock and low density of wild prey makes the former an attractive choice for wolves. The pastoral communities are very well aware of the movement of wolves because of their regular encounter with the species and are adversely affected by livestock depredation which causes high economic loss to them.

Methodology

Wolves in India generally reside outside PAs, areas which have low wild prey density, and thus are mostly dependent on livestock (Jhala 2003) which leads to frequent encounters with people (Msoffe et al. 2007). Utilising local community knowledge and observation can help in understanding the status of species in their surroundings (Ahmad et al. 2021). Methods for direct or indirect monitoring of carnivore populations are costly and time-consuming, especially at large spatial scales (Rich et al. 2013). However, the use of secondary information, like interview surveys, to determine the status of the species is both cost-effective and reliable which can help managers make short-term decisions for the conservation of the species (Gros et al. 1996, Msoffe et al. 2007, Mohd-Azlan et al. 2013, Ahmad et al. 2021). Furthermore, due to the low density of wolves in India, many studies looking at the status of the species were based on indirect methods like interview surveys from local shepherds; sign surveys, or a combination of both (Jhala and Giles 1991, Kumar and Rahmani 1997, Singh and Kumara 2006). In this study we used interview surveys and, to reduce misinformation errors, we selected eight local Village Wildlife Volunteers with experience of more than 10 years in conducting ecological surveys from different parts of the sanctuary to conduct the interviews among local people (Mohd-Azlan et al. 2013, Mahajan and Khandal 2019).

Wolves range across wide areas and occur in relatively low densities, therefore sightings of wolves are extremely rare (Jhala 2003). We were thus mostly dependent on indirect signs and information from the local villagers and shepherds. We conducted the ground survey in KWLS during July – October 2018. Indirect signs were collected from areas where direct sightings of wolves were not possible. We made several survey trips across the KWLS, covering a total of 1,050 km by motorbike and 455 km on foot in areas that are likely to support wolf populations, and searched intensively for wolf signs, such as tracks and scats. We conducted semi-structured questionnaire-based interviews in 13% of the total households present in each village, among local people and shepherds, and recorded information on the presence of wolves/wolf packs, number of livestock owned, livestock kills by wolves, compensation paid, villagers' attitudes, and sightings of dens (Mahajan and Khandal 2019). This information was corroborated by indirect signs from ground surveys. Areas of intensive agricultural use, human-habitation, and gorges, where wolf presence was not expected, were not surveyed thoroughly.

To avoid overestimation, we enquired about wolf numbers and wolf packs around the villages for the past 14 days. To ensure correct identification, and to differentiate between wolves, locally known as 'khodya', and other species present in the area such as Indian foxes (*Vulpes bengalensis*), golden jackals (*Canis aureus*), and Indian striped hyaenas (*Hyaena hyaena*), interviewees were shown photographs of different species and were asked to identify the species and provide all details of the sighting incident/s. Any ambiguity in the confirmation was treated as 'not sighted' and that record was not taken into account. We considered villages that come under one range as a single sampling unit (total ranges = 4). Assuming that a single pack roamed around a single range, the number of packs sighted by respondents of villages in close proximity to each other was considered as one pack to avoid overestimation (Kumar and Rahmani 1997). This was also confirmed with the number of wolves seen around those villages (i.e. if the same number of wolves were sighted around multiple villages, it was considered as one pack). For larger ranges like Nainyaki (258 km^2 area) and Mandrail (210 km^2 area), we considered two groups of villages (7 – 8 villages each in Nainyaki and 4 villages each in Mandrail; with an average area of 130 km^2 for each sampling unit) as a single unit. Therefore, in total we had six sampling subunits which were considered as a single unit occupied by a single pack of wolves. Wolves in KWLS use around 82% of the habitat (Mahajan et al. 2021, in review) and are frequently sighted in vast and remote areas of the sanctuary that are devoid of human disturbances. The villages in KWLS are closely clustered and surrounded by agricultural and grazing land, while the rest of the area is typical scrubland which is preferred by wolves (Jhala 2003).

To analyse the relation of livestock and wild prey with wolf presence we divided the KWLS into 48 grids of 14.4 km^2 each and extracted the wolf sign density, sheep density, goat density, and wild prey sign density from each grid (Appendix 1). To relate wolf sign density with both wild and domestic prey, we conducted a Pearson product-moment correlation test.

Results

We recorded a total of 175 wolf signs across the KWLS (Figure 2), with a maximum from the Nianyaki range (93 signs). Moreover, Nainyaki range also had the maximum livestock holding comprising 3,110 sheep and 15,079 goats (Table 1). Chinkara and nilgai were the only wild prey species in the KWLS and were present in low densities (Jhala et al. 2020) rendering livestock the major prey of wolves.

We found densities of 0.25 ± 0.04 wolf signs/km^2, 8.94 ± 2.44 sheep/km^2, 49.94 ± 9.50 goats/km^2, and 0.15 ± 0.03 wild prey signs/km^2 (Appendix 1). We related the wolf sign density with both wild and domestic prey and found that both sheep and goat densities showed a significant positive relationship with wolf sign density (product–moment r_{sheep}=0.514, d.f.=47, p<0.05; r_{goat}=0.44, d.f.=47, p<0.05), while the wild prey sign density showed a positive relation with wolf sign density, although not significant (product–moment r_{wild_prey}=0.139, d.f.=47, p=0.34).

Table 1. Number of wolf signs, sheep, goats, and human population in each range of Kailadevi Wildlife Sanctuary, Rajasthan.

Range	Area (km^2)	Wolf signs	Sheep	Goats	Human population
Nainyaki	258	93	3110	15079	7787
Kailadevi	142	39	2128	7768	6306
Karanpur	145	19	749	7427	2338
Mandrail	210	24	193	4245	1823

We conducted a total of 442 interviews across the KWLS, based on which we concluded that KWLS supports a minimum population of 19 and maximum of 45 wolves (32 ± 13) which we believe is a conservative estimate based on the experience of the interviewers and local knowledge of the people in KWLS (Table 2). The maximum number of wolves was present in the Nainyaki range (13 – 25), followed by the Mandrail range (3 – 7), Kailadevi range (1 – 8), and the Karanpur range (2 – 5). The estimated density of the wolves in KWLS ranges from 0.02 – 0.06 wolves/km^2. The Nainyaki range had the highest density of wolves (0.06). As reported by the villagers of Dangra in the Nainyaki range, the largest pack comprised 14 wolves. During the present study, sightings were rare although on one occasion we sighted a pack of 8 wolves in Nainyaki range while at other times packs of 2 or 3 wolves were sighted (Table 3). We observed a dead female wolf at 'Bhagat ka danda' near the Sakda village. The post-mortem report confirmed its death was due to a territorial fight with another wolf. We also encountered one wolf carcass during our survey which might have been dead due to poisoning, as was informed to us by the local villagers.

During our survey we located an abandoned den site near the village 'Veramki' in the Kailadevi range. The den in the past year had been used by a female wolf who gave birth to six pups, suggesting that the KWLS is a breeding habitat for Indian grey wolves. The den was located on an elevated surface between rocky outcrops 500 m away from the nearest village (Veramki) and covered by moderately dense vegetation all over with minimum visibility (Figure 3). The nearest gorge was at a distance of 1km, and the area within a 5 km radius of the den had a rocky and undulating terrain with sparse shrub cover and very little human disturbance. We also identified one rendezvous site at 'Bhagat Ka Danda', which was 1.5km away from the Sakda village in the Nainyaki range. Rendezvous sites are where pups are kept after they leave the natal den (Kumar 1998). This particular rendezvous site mainly had the dhonk (*Anogeissus pendula*) and *Zizyphus sp.* in its vicinity. The site also yielded indirect signs like wolf tracks from all the directions, strong odour of wolf urine, and particular smell of wolf presence, wolf scat and hair along with indications of rolling and scratch marks in the vicinity, indicating intensive use by wolves (Figure 4). The habitat within a 4 km radius of the rendezvous site was typical scrub forest with the nearest water body named as 'Gond ki Talai' located 3 km away. Other features included a relatively flat surface and minimal human disturbance. The description of rendezvous sites of wolves in Solapur, Maharashtra by Kumar (1998) matches extremely well with the rendezvous site identified in KWLS. Selection of rendezvous site is a function of availability of water, presence of remote area without human disturbance, and visual cover (Jhala 2003). We conducted our survey before the onset of breeding period; therefore, we were able to locate only one abandoned den site and one rendezvous site. Nevertheless, our survey and results clearly indicate that the presence of wolves in KWLS is not due to a few dispersing individuals but that the species is well adapted to the habitat of the sanctuary.

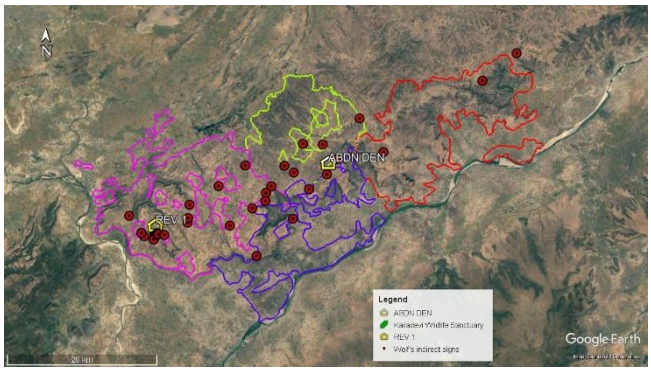

Figure 2 Wolf indirect signs collected in different ranges of KWLS along with the abandoned den site and rendezvous site. ABDN DEN refers to the abandoned den site and REV refers to the rendezvous site.

Figure 3 Rocky and undulating terrain with sparse shrub cover at the abandoned den site.

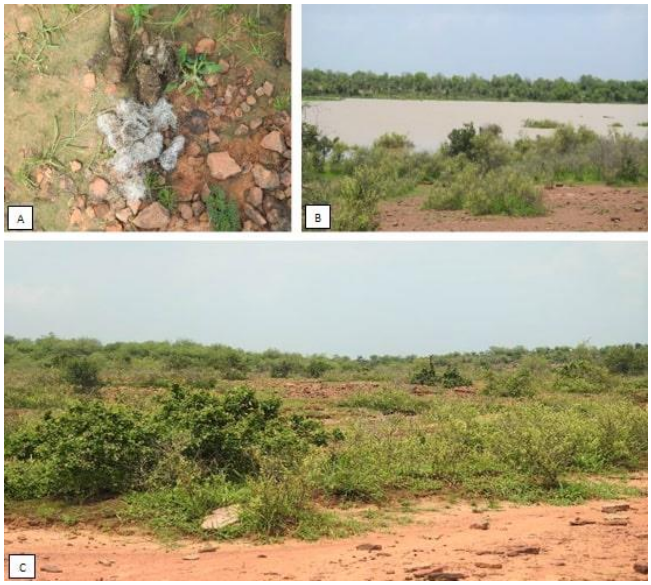

Figure 4 A. Wolf scat collected from the rendezvous site; B. A water source named "Gond Talai" 3 km away from the rendezvous site; C. Open and flat scrub forest in the vicinity of rendezvous site.

Discussion

The Indian grey wolf is known to be widely distributed in Rajasthan and the state supposedly has sparsely populated regions with suitable habitat for denning (Jhala and Giles 1991). At present only a few systematic studies in Rajasthan have assessed the ecological status of the Indian grey wolf at landscape scales using robust methods. Jhala and Giles (1991) estimated the wolf numbers in Sawai Madhopur district (when Karauli district was a part of Sawai Madhopur) to be around 6 – 10. Now three decades later we have provided a fairly reliable estimate of wolf numbers which we believe comes under the bracket of maximum and minimum number of wolves generated through our survey. Due to the lack of distinct morphological traits (body/pelage markings), abundance estimation methods that rely on individual identification from photogenic captures cannot be used on wolves. Robust methods like howling surveys, radio-collaring, or capture-recapture sampling using DNA analysis to identify individuals are better alternatives to estimate the population of wolves. However, due to logistic constraints and limited funds we conducted interview surveys to determine the status of wolves in the sanctuary (Anadón et al. 2009). Our study can be regarded as a steppingstone towards the conservation of wolves in the larger landscape, calling for more efforts towards identifying and conserving similar habitats which could act as a refuge for dispersing wolves.

Our efforts in searching for wolves and indirect signs were mostly focused on suitable habitat or other areas as described by the shepherds. It has been observed that the Indian grey wolf requires scrubland area having good vegetation to seek visual cover during the day (Jhala 2003, Kumar 1998) and as potential rendezvous sites, but increased human population, agricultural practices and a high density of livestock have led to degradation and fragmentation of the habitat rendering KWLS an open scrub forest. The percentage of vegetation cover at the rendezvous sites generally varies from 20 – 30% (Jhala 1991). We covered most parts of the table-top plateau regions, small parts of the ravines, and excluded gorges from our intensive surveys. Ravines are believed to support a healthy population of wolves (Khandal and Khandal 2013) but, during our survey, we did not find wolf signs probably because we conducted our survey during the post-monsoon season when wolves generally occupy the plateau region. From July to October, people from nearby villages move into the sanctuary along with their domestic animals to take advantage of fresh fodder. Villagers from a particular village graze their herd in self-designated forest areas and establish temporary cattle camps known as 'Khirkadis' (Tiger conservation plan 2015 unpublished report, Reddy 2008). Therefore, during the monsoon season, the total number of livestock inside the KWLS increases by almost two-fold (Das 2007; Reddy 2008). Our findings. based on indirect wolf signs, reported similar results as wolf signs were found to be significantly positively correlated with livestock presence. During the summer, Kailadevi residents migrate down to the ravines of the Banas, Morel, Chambal and Kalisil rivers, as there is a scarcity of water and fodder in the plateau region at this time of the year. During this period, wolves generally follow the shepherds towards the ravine regions in search of prey and water (Khandal, D. personal observation, Singh and Kumara 2006).

In KWLS, wolves share their habitat with several other species. Tigers, once locally extinct from KWLS (Reddy 2008), can today be seen inside the sanctuary which presently supports four tigers including two cubs born recently (The Times of India 2021). Successful conservation effort in Ranthambhore National Park (RNP) led to a surge in tiger numbers, but with its limited carrying capacity, the tigers began dispersing towards KWLS. Wolves and tigers practice natural spatial segregation in KWLS, as wolves generally prefer the table-top plateau with scrubland while tigers occupy the gorges which are covered with dense forests. Feral dogs (*Canis familiaris*) and wolves have been observed to interact multiple times, once seen sharing a carcass wherein dogs being more in number were dominant on wolves (Mahajan and Khandal 2019). Nayak et al. (2015) observed an interaction between hyaenas and wolves, wherein wolves were seen chasing the hyaenas away while feeding on the same carcass. Understanding these interactions is important to know the role of other species in wolf conservation (Singh and Kumara 2006).

Apart from its interactions with other carnivores, the Indian wolf forms an integral part of the KWLS community and has been coexisting with humans for centuries. Villagers in KWLS have been heavily dependent on forest resources for fodder needs and other requirements which resulted in overgrazing of the existing grassland. The resulting habitat degradation adversely affected the wild prey population. Moreover, medium-sized wild prey like chinkara is found in low densities in the study area (Reddy 2008, Jhala et al. 2020). These factors led to an increased wolf dependency on livestock for its dietary needs (Jethva and Jhala 2004). Livestock predation by wolves causes high economic losses to the villagers of KWLS (Mahajan and Khandal 2019) and in retaliation villagers often poison the predator and sometimes smoke and dig out dens to kill wolf pups (Jhala and Giles 1991). Besides being poisoned, wolves in KWLS were also poached for their skin to make a drum-like instrument called a 'Dhak', although such poaching cases are rarely observed now. Unlike some states that have reported cases of child lifting by wolves, KWLS has not witnessed such an occurrence (Shahi 1982, Jhala and Sharma 1997, Rajpurohit 1999).

Despite continuous persecution by human beings, the wolf has shown strong resilience to survive, chiefly due to its adaptability and intelligence (Kumar and Rahmani 1997). But, with aggravated habitat loss, fragmentation, and prey depletion its survival is severely threatened. KWLS is a highly human dominated landscape and also supports a good population of the Indian grey wolf, but with its open scrub forest without much cover, the changing habitat can endanger the survival of the species in the future. We suggest the following recommendations to help in conserving the wolf in the future:

1. Management plans involving development of large grassland plots with waterholes in wolf occupied areas should be adopted. Wolves frequently visit waterholes during summer therefore, they should be developed in areas where water can be retained annually and monitored at regular intervals. Kumar (1998) reported that wolves prefer plantation plots developed by forest department during the afternoon hours to seek visual cover and protection from the sun to regulate their body temperature. Therefore, appropriate areas should be maintained in wolf occupied areas to provide them with cover during the afternoon and to limit their interaction with people. More effort should be put in identifying potential den sites and protecting them with the help and support of volunteers and local communities. Moreover, urgent efforts should be put in restoring the degraded habitat and incentivized voluntary village relocation (Jhala et al. 2020) to create space for recovery of wild prey populations and reduce the pressure of predation on livestock (Meriggi et al. 2015).

Table 2 Estimated number and density of wolves in different ranges of Kailadevi Wildlife Sanctuary, Rajasthan.

Forest range	Village names	Min wolves	Max wolves	Density (wolves/km^2)
Nainyaki	Dangra, Sakda, Vishwanathpura, Matoriaki, Khateki, Dhodhaki, Hariki, Kalyanpura	8	15	0.05 – 0.09
	Pahadpura, Chondya Khurd, Daulatpura, Bangla Ki, Hatiya Ki, Ratanpura, Morochi	5	10	
	Total	13	25	
Kailadevi	Veeramki, Gondar Bura, Marmada, Khijura, Bhopara, Lakhruki, Nareki, Doltiya	1	8	0.007 – 0.05
	Total	1	8	
Karanpur	Kudka Math, Patoad, Chodiya Khata, Behrda, Asaki, Nibhera, Dagariya, Jhilpura	2	5	0.01 – 0.03
	Total	2	5	
Mandrail	Paton, Bamuda, Dayarampura	1	3	0.01 – 0.03
	Bhojpur, Gurja, Needar, Kuratki, Chirmil Ka Pura	2	4	
	Total	3	7	
	Total number of wolves	19	45	0.02– 0.06

Table 3 Description of wolves encountered in different ranges during the survey.

Forest Range	Places	No. of wolves encountered	Remarks
Nainyaki	Bhagat Ka Danda	8	During morning hours scrub forest with mainly *Anogeissus pendula* (Dhonk) and *Dichrostachys cineria* and the undergrowth vegetation consisted of *Grewia tenax* and 233 m away from rendezvous site
	Raja Dhonk	2	Near Uchi Guwadi village in evening hours
Kailadevi	Morochi Closure	2	In the shrub forest with dense vegetation cover during the afternoon hours.
	Peeli Talai ka danda	1	On the flat terrain crossing the road during evening hours
Karanpur	Asaki Plantation	1	A lone wolf during afternoon hours
	Dunde Neem ka danda	4	A pack of four wolves sighted during the evening hours
Mandrail	Dang ka danda	2	Near Bamuda village during the morning hours

2. An efficient livestock compensation scheme should be put in place to minimise negative attitudes among the villagers and prevent retaliatory persecution. The current schemes face several issues. Many people are unaware of such schemes, and those who are, often fail to provide photographic evidence because it is difficult to retrieve carcasses as wolves generally kill smaller livestock animals which they drag far off from the actual site of kill and usually consume them within a few hours after the kill (Krithivasan et al. 2009, Agarwala et al. 2010). On other occasions people do not apply for compensation because of the complexity involved with the documentation. To ensure timely compensation, awareness should be spread among the people about the scheme through public outreach. Forest staff should be trained to carry out field inspections and proper documentation. Methods involving the payment process should be simple and efficient. The transaction cost and the amount paid should not exceed the amount of the livestock loss.

3. In KWLS, domestic dogs are present in almost every village and are observed to interact with feral dogs at kill and feeding sites, with the latter further interfering with wolves (Khandal, D. personal observation). Dogs can act as a reservoir for diseases like canine distemper virus (CDV) and rabies, besides transmitting hepatitis, provirus, and a multitude of other infections to wolves (Jhala and Giles 1991). We thus recommend complete eradication of feral dogs from KWLS to conserve the wolf population in the long term. Disease transmission from domestic dogs can also be prevented by vaccinating dog populations living within and around wolf occupied areas.

4. By providing economic benefits to local people, particularly through ecotourism, employment, and compensation for livestock losses by wolves, we can help in reducing the negative perceptions of villagers towards the species (Sillero-Zubiri and Switzer 2004).

5.To better understand the dynamics of wolves and their interactions with the resident people of KWLS, intensive studies on the movement, dispersal, habitat requirements, and general ecology of the former should be done using radio-telemetry techniques. Alternatively, regular estimation of wolf numbers should be carried out at least once every two years using robust techniques.

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Biographical sketch

Dharmandra Khandal is a conservation biologist who has been with Tiger Watch since 2003. His work with Tiger Watch has involved proactive anti-poaching, the monitoring of wildlife and conservation research. He has forged new frontiers in the world of community-based conservation through his interventions in the Ranthambhore Tiger Reserve.

Prashant Mahajan is working as Project Fellow at Wildlife Institute of India. He has previously worked on species including tigers, wolves, and elephants which involved population estimation studies using camera trapping and behaviour studies using radio telemetry techniques. His interest lies in large carnivore ecology, prey-predator relationships, and human-carnivore conflict.

Appendix 1

Density of wolf signs, sheep, goats, and wild prey within each grid in Kailadevi Wildlife Sanctuary. In the grid name column KR refers to the grids Karanpur range, K refers to the grids Kailadevi range, N refers to the grids in Nainyaki range, and M refers to the grids in Mandrail range.

Grid name	Wolf sign density (signs/km^2)	Sheep density (sheep/km^2)	Goat density (goats/km^2)	Wild prey sign density (prey/km^2)
KR9	0.35	40.69	141.04	0.00
KR8	0.83	8.06	299.72	0.14
KR3	0.14	3.13	24.65	0.00
KR4	0.00	0.00	0.00	0.14
KR5	0.00	0.00	0.00	0.14
KR6	0.00	0.14	50.35	0.42
K10	0.49	63.19	190.42	0.14
K9	0.07	25.56	106.94	0.42
K1	0.07	0.00	0.00	0.21
K2	0.42	35.21	80.07	0.28
K3	0.56	23.82	130.21	0.14
K4	0.28	0.00	0.00	0.07
K5	0.00	0.00	0.00	0.00
K6	0.21	0.00	0.00	0.49
K7	0.35	0.00	0.00	0.07
K8	0.28	0.00	31.81	0.63
N19	0.21	4.03	73.61	0.07
N18	0.97	33.06	73.68	0.42
N17	0.35	3.89	52.36	0.00
N16	0.07	2.36	29.24	0.21
N15	0.00	2.92	62.92	0.21
N1	0.00	14.86	80.14	0.28
N2	0.28	0.21	26.25	0.21
N3	0.28	11.39	184.79	0.00
N4	0.42	3.89	40.07	0.07
N5	0.49	3.61	21.81	0.76
N6	0.28	0.00	0.00	0.07
N7	0.69	55.97	152.71	0.21
N8	0.90	7.29	41.88	0.00
N9	0.69	65.07	80.35	0.14
N10	0.35	7.22	28.89	0.00
N11	0.00	0.00	0.00	0.00
N12	0.00	0.21	98.47	0.00
N13	0.07	0.00	0.00	0.00
N14	0.42	0.00	0.00	0.00
M1	0.14	0.00	0.00	0.21
M2	0.07	0.00	11.53	0.00
M3	0.14	7.50	16.11	0.00
M5	0.07	0.00	0.00	0.07
M6	0.07	0.00	0.00	0.35
M7	0.00	0.00	27.99	0.00
M8	0.42	0.00	0.00	0.00
M9	0.00	0.00	0.00	0.07
M10	0.07	0.14	175.49	0.00
M11	0.00	0.00	0.00	0.00
M12	0.28	5.76	14.44	0.14
M13	0.00	0.00	0.00	0.07
M14	0.42	0.00	49.24	0.21
Mean	0.25	8.94	49.94	0.15
Standard Error	0.037	2.44	9.51	0.03