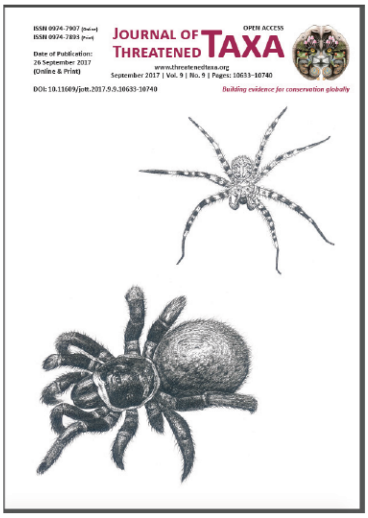

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Communication

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Chhimi Namgyal & Phuntsho Thinley

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Abstract: The Dhole is a little-studied wild canid with decreasing populations throughout its global range. We conducted this study in Bhutan's Jigme Dorji National Park (JDNP) to establish baseline records of Dhole distribution and habitat use. We used trail transects and recorded animal presence via tracks, scats, direct sightings and camera traps. Ancillary habitat characteristics such as elevation, slope and vegetation cover were recorded to characterise habitat use. We used MaxEnt model to estimate distribution within JDNP. We recorded 609 indicators of Dhole presence over a 60-day survey period. The model estimated almost one-fourth of JDNP as having a high probability of Dhole occurrence, which closely corresponds to the distribution of cool broadleaved forests (CBLF) and areas close to human settlements. The highest number of indicators was obtained from CBLF, between slope ranges of 2 – 38 degree and elevation ranges of 1,468 m – 4,620 m above sea level, indicating a new record upper altitude limit for Dhole distribution across its global range. We highlight JDNP as an important Dhole conservation area in the Eastern Himalayas, and recommend drafting a pragmatic conservation plan that will strive to minimize conflicts with livestock owners and include key components such as farmer education and livestock insurance to cover Dhole kills.

Keywords: Bhutan, Dhole conservation, Dhole distribution, eastern Himalaya, endangered carnivore, habitat use, Jigme Dorji National Park.

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Author Contribution: Both the authors have equally contributed in field data collection, data analysis, and drafting of the manuscript.

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INTRODUCTION

The Dhole *Cuon alpninus* (Pallas, 1811) is commonly known as the Asiatic Wild Dog, Indian Wild Dog, or Red Dog. Depending on the regions where it is found in Bhutan the Dhole is referred to as 'phaw' (in Dzongkha, the national language), 'rom' (in Tshangla, the eastern Bhutan dialect), 'tsawaring' (in Khengkha, the central Bhutan dialect), and 'ban-kukur' (in Lhotshamkha, the southern Bhutan dialect). It is considered 'Endangered' by the IUCN Red List (Kamler et al. 2015).

The Dhole is native to Asia, and it is currently found in Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, and Thailand. It is thought to have been extirpated from Central and East Asia, the Korean Peninsula, Singapore and possibly Vietnam. At present this threatened wild dog is facing a decreasing population trend across its entire distributional range, primarily due to retaliatory killings and a decrease in prey base (Durbin et al. 2004; Kamler et al. 2015).

Dholes are post-Pleistocene in origin and are more closely related to jackals than wolves according to Thenius (1954), as cited by Johnsingh & Acharya (2013). The species was first described in 1794 by Pesteref during his travels in far eastern Russia (Heptner et al. 1998), and was given the scientific name *Canis alpinus* by a German Zoologist Peter Simon Pallas in 1811 (Pallas 1831). The number of Dhole subspecies is debatable, but 11 have been identified based on differences in coat length and colour (Durbin et al. 2004). According to Wangchuk et al. (2004), the subspecies *C. a. primaevus* is found in Bhutan.

Like its other sympatric carnivores in the Indian subcontinent such as the tiger *Panthera tigris* and the common leopard *Panthera pardus* (Karanth & Sunquist 1995), the Dhole is an important predator. In Bhutan, the Dhole regulates populations of wild ungulates such as Sambar *Rusa unicolor*, Muntjac *Muntiacus muntjac*, Gaur *Bos gaurus*, Himalayan Serow *Capricornis thar*, Goral *Naemorhedus goral*, Wild Pig *Sus scrofa* and primates such as the gray langur *Semnopithecus schistaceus* and Assamese Macaque *Macaca assamensis* (Wangchuk 2004; Wang & Macdonald 2009; Thinley et al. 2011).

Despite its ecological significance as one of the apex predators with an 'Endangered' status, the Dhole has received little attention from conservationists and researchers. Thus, it is one of the least studied and most neglected among the wild carnivores (Srivathsa et al. 2014) and there is very little information on Dhole distribution. This information gap is largely attributed to its persistent predation on domestic livestock. For instance, it was once almost extirpated from Bhutan in the 1980s in a massive poisoning campaign (Wangchuk 2004; Thinley et al. 2011) because of its excessive predation on domestic livestock. In a recent questionnaire survey on livestock loss in western Bhutan Katel et al. (2015) observed that Dholes killed more livestock compared to common leopards and tigers.

There is currently no reliable information on Dhole distribution and habitat use in Bhutan, although cases of livestock depredation by Dholes are periodically documented. In the absence of such basic ecological information, there is no realistic conservation plan for the Dhole in Bhutan. Now that this endangered dog has fairly re-established its population in the country, contrary to the popular local belief of having been introduced by the government (Wangchuk 2004), there is an urgent need to understand its distribution pattern and habitat use to monitor and detect any massive disruptions to populations and distributions. Therefore, with the goal of enhancing ecological information on the Dhole we studied the species' distribution and habitat use in western Bhutan. We have also modelled its distributional extent using the latest prescribed species distribution model.

MATERIALS AND METHODS

Study area descriptions

We conducted the study in Jigme Dorji National Park (JDNP), which is located in the northwestern part of Bhutan between the geographical coordinates of 27°33' N to 28°15' N and 89°16' E to 90°16' E. Covering an area of approximately 4,317km^2, JDNP is the second largest protected area in Bhutan (Fig. 1). The park shares an international border with the Tibetan Autonomous Region of China in the north. The elevation ranges from 1,200m in the south to 7,314m in the north. The areas above 6,000m are mostly covered with snow (Thinley et al. 2015b).

JDNP is one of the richest parks in Bhutan in terms of biological diversity and a hotspot for canid and felid diversity. So far, seven cat species – including the Tiger and Snow Leopard *Panthera uncia,* and four canid species – including the Gray Wolf *Canis lupus*, Red Fox *Vulpes vulpes*, and Asiatic Jackal *Canis aureus,* have been recorded in the park (Thinley et al. 2015a). Seven species of ungulates have also been recorded – including the endemic Bhutan Takin *Budorcas taxicolor whitei*, the endangered Himalayan Musk Deer *Moschus leucogaster*, and the endangered Alpine Musk Deer *Moschus*

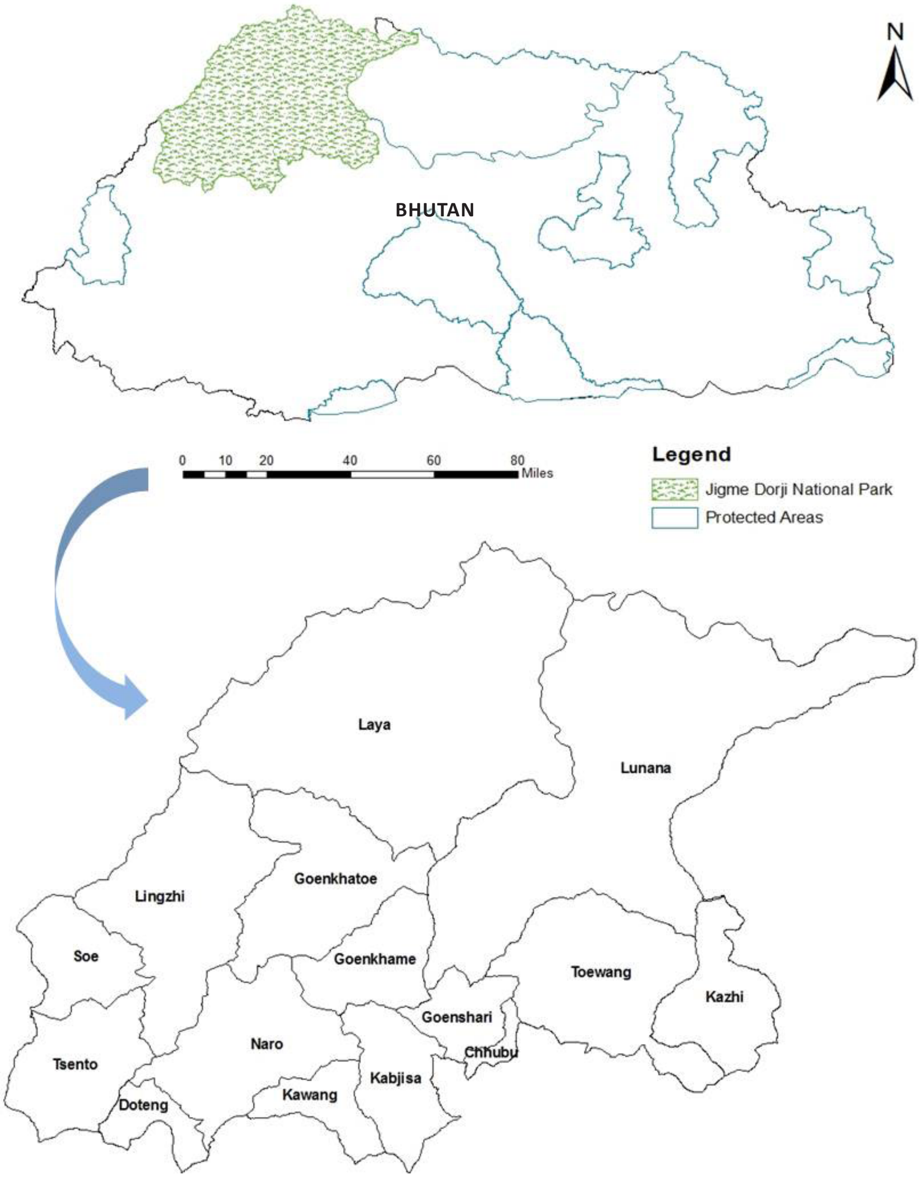

Figure 1. The map of protected areas of Bhutan showing the study area (above), Jigme Dorji National Park with the administrative geography or sub-districts (below).

chrysogaster. Floristically, the park has 1,434 recorded species of vascular plants of which 300 are medicinal. Annually, the highest quantities of the expensive Chinese Caterpillar *Ophiocordyceps sinensis* are collected from the park (Thinley et al. 2014, 2015a,b).

Field data collection

Initially, a preliminary presence-absence questionnaire survey was conducted among park staff and villagers within the park in order to get a sense of whether Dholes were present in their locality. This rapid assessment helped in careful planning of our survey.

In order to investigate Dhole distribution, we adopted the trail transect method used by Thinley et al. (2011), because Dholes are known to use regular trails. We surveyed all major human and animal paths for 60 days from 1 February to 1 April 2016 and looked for Dhole presence, namely, sightings, tracts or foot prints, and scats or faeces. The Field Guide to Mammals of Bhutan (Wangchuk et al. 2004) was used to identify Dhole scats and tracks. Recognizing the potential confusion between Dhole tracts and scats and those of sympatric canids and felids, we only considered numerous scats and tracts observed in a straight line along a tract which could be unmistakably attributed to a Dhole pack. We also made use of 108 camera traps stationed in the park for zoning purpose. We recorded additional habitat characteristics where Dhole signs were observed: a) location – recorded in geographical coordinates using a hand-held GPS (Global Positioning System) unit; b) elevation

– in meters measured using an altimeter; c) slope – in degrees measured using a clinometer; d) aspect – in cardinal directions determined using a compass; and e) vegetation characteristics or forest type – characterised by dominant tree species. Location, elevation, and slope were recorded at the centre of a scat or track group. We also recorded the presence of various prey species, including domestic livestock in the vicinity of Dhole signs to check what type of prey species are followed by Dholes.

Data analysis

For modelling Dhole distribution we used MaxEnt (version 3.3.3k), a computer programme for modelling species distribution in ecology. The model uses presence-only data of the target species – basically a set of occurrence data – and some environmental variables or covariates to produce a surface of the probability of occurrence (Phillips et al. 2006; Elith et al. 2010). In the model, the influence of each environmental variable on the species' distribution is assessed, and the mean values of the variables are used for the whole landscape of interest. Ultimately, a surface corresponding to the maximum entropy probability of distribution is produced to best reflect the probability of distribution of the target species (Phillips et al. 2006; Papeş & Gaubert 2007).

In MaxEnt, we used five environmental variables that were deemed to affect Dhole distribution. These are elevation, slope, aspect, land cover, and distance from human settlement. We collected the spatial layers for these variables which were then processed in GIS (Geographic Information System) environment using ArcGIS™ (version 10.3). All the layers were converted to raster format with a standardized cell size of 30 m, in line with the standard projection and coordinate system for Bhutan (i.e., PCS_DRUKREF_03_TM), and the geographic extent of JDNP boundary. As with Jenks et al. (2012), we used the default setting in MaxEnt model of 500 iterations with convergence threshold of 0.00001, a regularization multiplier of 1, and a maximum background point of 10,000, but with 50 random test percentage using JDNP boundary as the mask. We assessed the model's performance using the AUC (Area under the Receiver Operating Curve). The AUC values range from 0.5 to 1.0 such that values closer to or equal to 0.5 indicate very poor fit whereas those closer to or equal to 1 indicate perfect fit (Fielding & Bell 1997).

Dhole occurrences in different habitat parameters – slope, elevation, aspect, and habitat types– were assessed using the statistical programme R (R Core Team 2015). A non-parametric Kruskal-Wallis test was performed to check the relationship between the habitat parameters and the number of Dhole evidences. Post-hoc analyses were performed using the package "pgirmess" (Giraudoux 2014) and function "kruskalmc" (for Kruskal-Wallis one-way analysis of variance) in R to check which pair of factors showed significant differences.

RESULTS AND DISCUSSION

Dhole evidences

We encountered 41 Dhole tracks and 522 Dhole scats during the sampling period of 60 days, which covered 256km of trails. This translated to a sign encounter rate of 2.2 signs per km of trail walked. As a comparison, a study conducted by Ramesh et al. (2012) in Kalakad-Mundanthurai Tiger Reserve in India's Western Ghats observed sign encounter rate of 0.67 signs per km (from 353.2km of transect length and 237 signs). We also obtained 46 Dhole images from 46 camera trap stations (Image 1). In summary, a total of 609 Dhole evidence were obtained from 170 locations inside the park (Fig. 2). Most of the evidences were observed in areas situated closer to human settlement. This could be because we saw more evidence of Dhole prey, such as wild pig and sambar, near human settlements than in areas further away into the deep jungle. Such a high relative abundance of wild ungulates near human settlements was also observed by Thinley et al. (2017) in the same park, which further explains the current pattern of Dhole occurrences near human settlements.

Dhole distribution

Judging from the geographical locations of evidence,

Image 1. A Dhole pack captured by one of the camera traps stationed in Jigme Dorji National Park for zoning purpose.

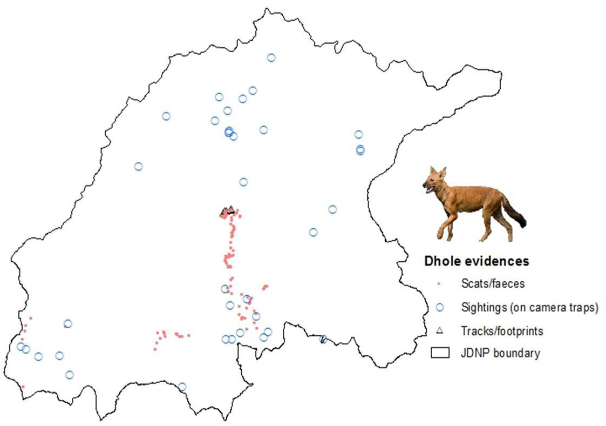

Figure 2. Dhole occurrences in Jigme Dorji National Park based on location of evidences, such as tracks, sightings, and scats.

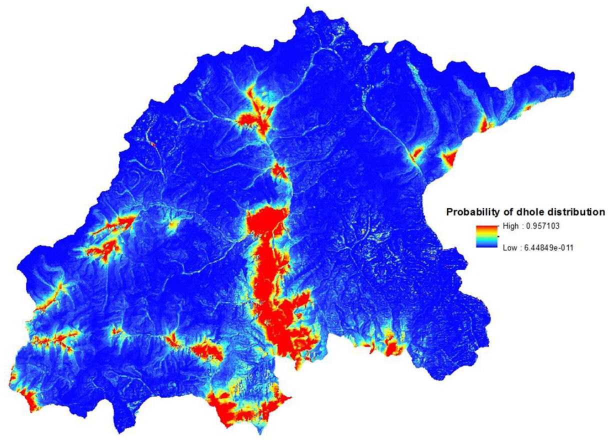

Figure 3. Probability of Dhole distribution in Jigme Dorji National Park. The red and yellow colours show areas with better prediction.

Dholes were distributed in settlement areas with high livestock populations (Fig. 1), specifically in proper Laya, Tsharijathang and Lungo villages of Laya 'geog' (a Dzongkha term for a sub-district or an administrative block); Ramina, Wachey, Threga, Lheydi and Tenchoe villages of Lunana goeg; all villages of Khatoe, Khamoe, and Goenshari geogs; Kewana and Neptengkha villages of Tewang geog; Gangyul and Chebisa villages of Lingzhi geog; Zhomthang, Waza, Zhodue, and Barshong villages of Naro geog; all villages of Soe geog; Yaktsa, Shana, and Chuyuel villages of Tsento geog; Dodeyna, Begana, and Kuzhuchen villages of Kawang geog; and Girigang, upper Tongshina, and upper Tsheteyna villages of Kabji geog. Coincidentally, these areas were also the livestock depredation hotspots for Dholes, as many cases of livestock losses and damages by Dholes have been reported to the park management from these areas (Leki, pers. comm. JDNP 22 July 2016).

The MaxEnt program predicted almost one-fourth of the park's total surface area as having a high probability of Dhole occurrence (indicated by red areas in Fig. 3). These high probability areas are situated close to human settlements, and correspond to CBLF (cool broadleaved forest) and mostly lower elevations. The model performed very well with AUC values of 0.946 for training data and 0.922 for test data (Fig. 4). Our model was heavily influenced by the variable "distance from human settlement", as it contributed 61% of the model gain (Table 1). This is realistic because most of the Dhole evidences were gathered from areas close to human settlements. The variable "slope" contributed the least to model gain with only 1.9%, indicating that slope is not an important factor for Dhole distribution. Likewise, the variable "Land cover" (implicit of vegetation cover) also contributed merely 2.7%. This could be because Dholes are found in wide range of land cover types (Jenks et al. 2012).

For a dataset like ours, MaxEnt is currently the only viable choice of species distribution model as the data on occurrence of Dholes were collected as "presence only" from certain locations, without systematic and true absence data (Phillips et al. 2004; Elith et al. 2010). The other models such as the Generalized Linear Model and Generalized Additive Models require true absences which are difficult to prove within a short study period as ours (Phillips et al. 2004). The MaxEnt model could provide good distribution data from even a limited number of occurrence data points (Phillips et al. 2004, 2006). In fact, the model has already been successfully applied to predict Dhole distribution in Thailand by Jenks et al. (2012). Therefore, we believe that the MaxEnt model of Dhole distribution in JDNP is highly reliable considering the appropriateness of the model used and its high predictability indicated by high AUC values.

Dhole habitat use

We found Dhole evidence in seven different vegetation types in JDNP: CBLF, MCF (mixed coniferous forest), BPF (blue pine forest), CF (chirpine forest), FF (fir forest), HF (hemlock forest), and AM (alpine meadows). The highest number of Dhole evidence (n = 426) were recorded from CBLF and the least from CF (n = 2). A similar pattern was also observed by Thinley et al. (2015a) in the same park during a camera trap survey in 2012. There was a highly significant difference in the number of Dhole evidence among the vegetation types (Kruskal-Wallis chi-squared = 33.8249, df = 6, $p < 0.005$). Post-hoc analysis showed significant differences in the number of evidences between the CBLF and AM, CBLF and FF, and AM and HF.

Table 1. Relative contributions of the environmental variables to the MaxEnt model of Dhole distribution in Jigme Dorji National Park, Western Bhutan.

Variable	Percent contribution	Dhole evidence Relation with Variable
Distance from human settlement	61	More evidence closer to human settlement
Elevation	27.1	Significant, Negative
Aspect	7.2	Not clear
Land cover	2.7	Wide range of land covers are associated
Slope	1.9	Appear insignificant

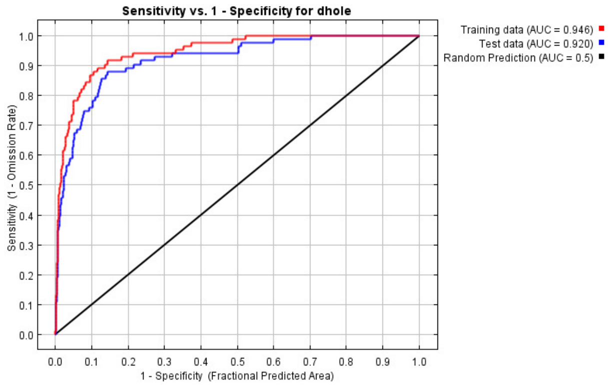

Figure 4. The area under the receiver operating curve (AUC) for Dhole distribution data.

The Dhole, however, is indeed a habitat generalist; it can be found in a wide array of forest or vegetation cover types from dense forest in Thailand to alpine areas in Russia (Kamler et al. 2015). Particularly in southern India, Dholes are seen mostly in forests and thick jungle (Krishnan 1972) as cited by Johnsingh & Acharya (2013). At any rate, Dhole distribution may be largely influenced by availability of appropriately sized prey, dense cover, and high tree densities (Karanth & Sunquist 2000).

Dhole evidences were observed in JDNP between an elevation range of 1,468m to 4,620m. This upper limit of 4,620m is the highest elevation record of Dhole occurrence throughout its entire distributional range. Elevation as a habitat characteristic correlated significantly negative to the number of Dhole evidences (β = - 0.001, SE = 0.0002, t = -4.632, and $p < 0.05$), indicating the Dholes' general preference for lower elevations where prey populations, including livestock, are usually higher. Comparing the result to studies in the region, Aryal et al. (2015) in Nepal's Dhorpatan Hunting Reserve encountered Dhole signs mostly at elevations higher than 2,500m. In a camera trap survey of Dholes in Sikkim's Khanchendzongkha Biospehere Reserve by Bashir et al. (2014), Dhole images were obtained from sub-alpine forests between the elevations of 3,100 to 3,900 and in alpine zone at 4,100m.

With regard to slope utilization, Dhole evidences were observed between 2 to 38 degrees (with μ = 17.7 degree and SD = 6.2 degree); this shows the Dholes' preference of gentle slopes. There was negative correlation between slope and Dhole evidence, but the relationship was not significant (β = - 0.0173, SE = 0.03, t = -0.664, and p = 0.508). This is plausible, because Dholes are also known to select sloped land in Nepal (Aryal et al. 2015) which has a similar geographical feature as in Bhutan.

When it comes to aspect utilization, we observed Dhole evidences mostly in north-east (n = 236) and north-west (n = 203) aspects. It is not known how aspect determines Dhole distribution, but the variable has contributed only 7.2% to model gain in MaxEnt (Table 1).

Scat size

Judging from the number of fresh and moderately fresh scats of same age and content deposited along the trails, we have determined the scat size ranging from 2 to 12 which is similar to 2 to 13 observed by Thinley et al. (2011) in the same park in 2009. This suggests that Dholes in JDNP have been stable since 2009.

CONSERVATION IMPLICATIONS

Our study provides the first information on Dhole distribution in a protected area in Bhutan. We have predicted Dhole occurrence in space as well as across various habitat variables. Through this study we have established a baseline for Dhole distribution in JDNP, which could be used for future monitoring, and detecting changes in distribution patterns. Despite the global decline in Dhole populations, JDNP holds promise as an important Dhole conservation area in the eastern Himalaya.

We have seen a new record of Dhole occurrence at a very high elevation (4,620m) overlapping with the Snow Leopard, which occurs between 3,800m and 5,200m (Thinley et al. 2014). An in-depth study is warranted to investigate the potential existence of dietary overlap between these two predators. In addition, we also observed that Dholes are mostly located near human settlements, thereby increasing the human-Dhole interface. This situation needs to be studied in detail to predict any ecological and/or social implications.

Now that Dholes have become well-established in JDNP, the park management needs to develop a conservation plan to minimize their predation on domestic livestock. The park staff could educate the livestock owners on the ecological roles and benefits of Dhole conservation with respect to their control on wild herbivores, some of which are also crop depredators. Concurrently, recently piloted reconciliatory conservation initiatives, such as a livestock insurance scheme which has proven successful in the park, should be up-scaled with increased premiums, endowment and coverage extending to incidents caused by Dholes, in order to dissuade retaliatory killings similar to those of the 1980s.

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