Distribution and potential habitat of the Vulnerable Himalayan wolf *Canis lupus chanco* in Bhutan

Tashi Dhendup [*1], Letro[1], Tandin[2] and Sonam Wangdi[1]

Abstract The rare Himalayan wolf *Canis lupus chanco* is categorized as Vulnerable on the IUCN Red List, and there is limited knowledge of its ecology and distribution. In Bhutan, the Himalayan wolf is one of the least known carnivores. Our aims in this study were to map the current distribution of the wolf in Bhutan and to identify potential habitats within the country. We compiled 32 records of wolf presence from camera-trap surveys and, using a maximum entropy approach, we estimated a potential habitat of 2,431 km², comprising c. 6.3% of Bhutan. However, wolf presence was localized and non-continuous. We recommend a detailed fine-scale habitat analysis in areas of potential habitat and genetic studies to investigate population structure. Knowledge of these matters will provide insights regarding connectivity and facilitate the development of conservation strategies for this threatened wolf.

Keywords Bhutan, camera-trap surveys, *Canis lupus chanco*, distribution, Himalayan wolf, *MaxEnt*, maximum entropy

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The grey wolf *Canis lupus* is widely distributed across North America, Europe and Asia, yet faces extirpation in some locations, resulting in a distribution restricted to wilderness and remote areas (Boitani et al., 2023). A subspecies of the grey wolf, *Canis lupus chanco*, known as the Himalayan or Tibetan wolf, inhabits the Himalayas and Tibetan Plateau, and possesses unique genetic adaptations to high-altitude habitats (Werhahn et al., 2018; Joshi et al., 2020). Categorized as Vulnerable on the IUCN Red List, it has been estimated there are < 4,000 mature individuals, with a projected continuous decline (Werhahn et al., 2023). Although the wolves in Bhutan are most likely of the Himalayan subspecies, this has not yet been confirmed.

Little is known about the Himalayan wolf. It occurs in the upper trans-Himalayan region of India, Nepal, the Tibetan plateau and northern Bhutan. In Nepal, the wolf is highly threatened, with < 50 mature individuals recorded, and it is categorized nationally as Critically Endangered (Jnawali et al., 2011). In Bhutan, the Himalayan wolf is rare and has been recorded mainly in the high alpine areas of Wangchuck Centennial and Jigme Dorji National Parks and Jigme Khesar Strict Nature Reserve. These records have been consistently associated with instances of livestock depredation (Wangchuk, 2004).

We compiled records of the wolf in Bhutan from bycatch in a snow leopard *Panthera uncia* survey during 2022–2023, which covered the northern protected areas and territorial forest divisions at elevations of 3,400–5,200 m (NCD, 2023; Plate 1). The survey area was divided into a 2 × 2 km grid, with a camera-trap station installed in each grid cell, at a location with high probability of snow leopard detection. Each camera-trap station consisted of two cameras, facing each other, to capture both flanks of passing animals. From August 2022 to January 2023, camera-trap stations were deployed across 310 locations. Additionally, we added one wolf record from a nationwide tiger *Panthera tigris* survey conducted during 2021–2022 and one from a survey for Pallas's cat *Otocolobus manul* in Jigme Dorji National Park in 2022.

To identify potential wolf habitats across Bhutan, we conducted habitat suitability modelling utilizing *MaxEnt 3.4.0* (Philips et al., 2006; Supplementary Material 1). Prior to modelling, we checked for spatial autocorrelation amongst the records, retaining only one point per 1 × 1 km grid cell across the study area (Lham et al., 2021). A default *MaxEnt* model was implemented containing variables that included 19 bioclimatic variables, slope, aspect, elevation and land cover (see Supplementary Material 1 for details). We subsequently excluded variables contributing < 1% to the model (Gong et al., 2023). We then assessed the remaining variables for multicollinearity using the *vifcor* function, with a correlation threshold of 0.75, in the package *usdm* (Naimi et al., 2014) in *R 4.3.1* (R Development Core Team, 2023).

We obtained 32 wolf presence points: 25 in Wangchuck Centennial National Park, four in Paro Forest Division, two in Jigme Dorji National Park and one in Jigme Khesar Strict Nature Reserve. From the nationwide snow leopard survey, the relative abundance index (calculated as the number of captures divided by the total sampling effort in days multiplied by 100) of wolves was 0.22, and the naïve occupancy (calculated as the number of camera-trap locations at which we detected wolves divided by the total number of camera-trap locations) was 0.1. The number of individuals captured per independent event was 1–4. The altitudinal range of grey wolf presence was 4,281–5,090 m.

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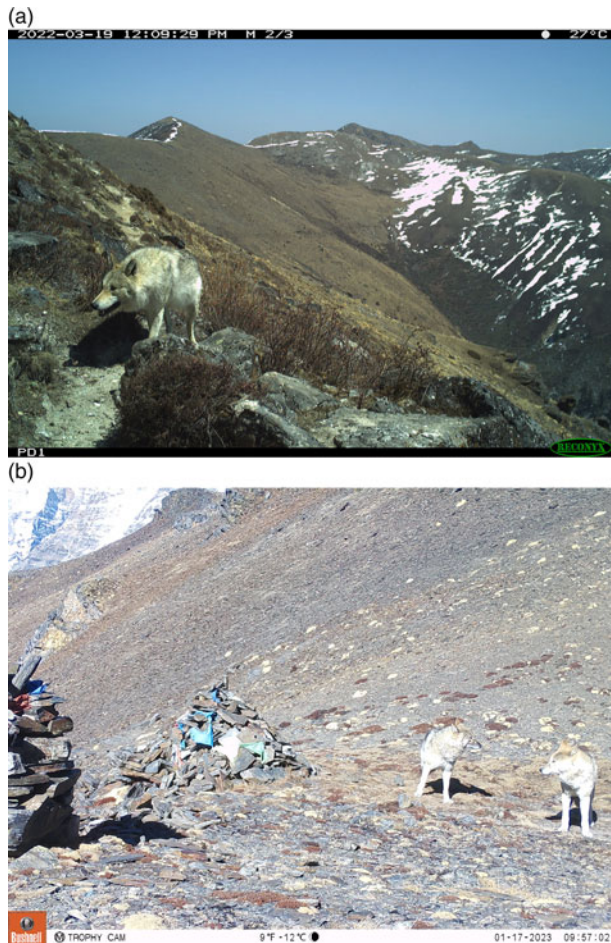[2] WWF Bhutan, Kawajangsa, Thimphu, Bhutan

PLATE 1 (a) A Himalayan wolf *Canis lupus chanco* camera-trapped in Paro Forest Division in western Bhutan (elevation 4,557 m). (b) Two Himalayan wolves photographed at a high altitude pass between Soe and Lingzhi region of Jigme Dorji National Park (elevation 4,882 m).

The majority of wolf records occurred in alpine meadows (18 of 32), followed by juniper forests (6), rocky outcrops (3), scrubland (3), and ridge (1) and screed slopes (1). Amongst the camera stations, those strategically placed on ridgelines (13 of 32) recorded the highest number of wolf occurrences, followed by those on trails (11) and at the base of cliffs and valley bottoms (4 each). After checking for spatial autocorrelation, we used 31 location points for the *MaxEnt* model. The model demonstrated a high discriminatory power (area under curve = 0.970), estimating 2,431 km² of potential habitat in Bhutan (Fig. 1). The mean temperature of the warmest quarter (BIO10) was the most influential variable (Table 1).

There was a greater number of wolf records from Wangchuck Centennial National Park than in other locations. Despite extensive coverage in the nationwide snow leopard survey and reportedly having a high density of blue sheep *Pseudois nayaur*, which is a preferred wild prey for wolves in Bhutan, there were fewer wolf records in Jigme

Dorji National Park. There were no wolf records in Bumdeling Wildlife Sanctuary in the east, although the *MaxEnt* model predicts the presence of suitable habitat in the area. Discrepancies in prediction of suitable habitat by *MaxEnt* may arise if there are no records from particular regions or if ecological factors, such as prey availability, are not included in the model. Further research is required to identify key ecological variables for a detailed fine-scale habitat analysis in areas of potential habitat (Červinka et al., 2013; Rich et al., 2017; Wolf & Ripple, 2018). Jigme Khesar Strict Nature Reserve is proximal to the Indian state of Sikkim, where there have been wolf sightings (Choudhury, 2015), and it is possible that wolves move between these areas. Investigating gene flow and connectivity amongst wolf populations in Bhutan and neighbouring regions would provide a better understanding of genetic diversity, population structure and the impacts of barriers on gene flow. Knowledge of these matters is essential for effective conservation strategies, particularly within the broader Himalayan and Tibetan contexts.

In the Himalayas and Tibet, wolves rely on domestic prey as well as on wild prey species (Lyngdoh et al., 2020; Shrotriya et al., 2022). In Bhutan, blue sheep comprise the main wild prey of the wolf in high-altitude regions, with blue sheep densities relatively higher in western areas and declining towards the east (Lham et al., 2021). Other potential prey species include the Himalayan musk deer *Moschus chrysogaster*, marmot *Marmota himalayana*, goral *Naemorhedus goral* and serow *Capricornis thar* (NCD, 2023). Livestock also comprise a significant proportion of wolf prey, particularly in regions with limited natural prey and suboptimal livestock husbandry, as reported in the higher altitudes of Wangchuck Centennial National Park (Jamtsho & Wangchuk, 2016; Lyngdoh et al., 2020). Wolves frequently prey on livestock in the Park, especially adult yaks, resulting in economic losses that are nearly double those attributed to snow leopards and fostering negative attitudes towards wolves and other predators (Jamtsho & Katel, 2019). The absence of compensation for livestock losses increases the risk of persecution of wolves and threatens the long-term persistence of the species in Bhutan. Anecdotal sources describe a near extirpation of the wolf population in some parts of the country, and suggest that local people set fires in denning caves.

We have described the grey wolf distribution in the Bhutan Himalayas for the first time, and our findings suggest a restricted range for the species, in < 7% of the country. The IUCN Red List indicates wolf range in > 50% of Bhutan (Boitani et al., 2023), implying wolves are widespread across northern Bhutan. Our findings will help inform a revision of this assessment. There is a need to examine the dynamics of human–wolf conflict in Bhutan, for designing appropriate intervention strategies to minimize any conflict. A study of wolf diet using
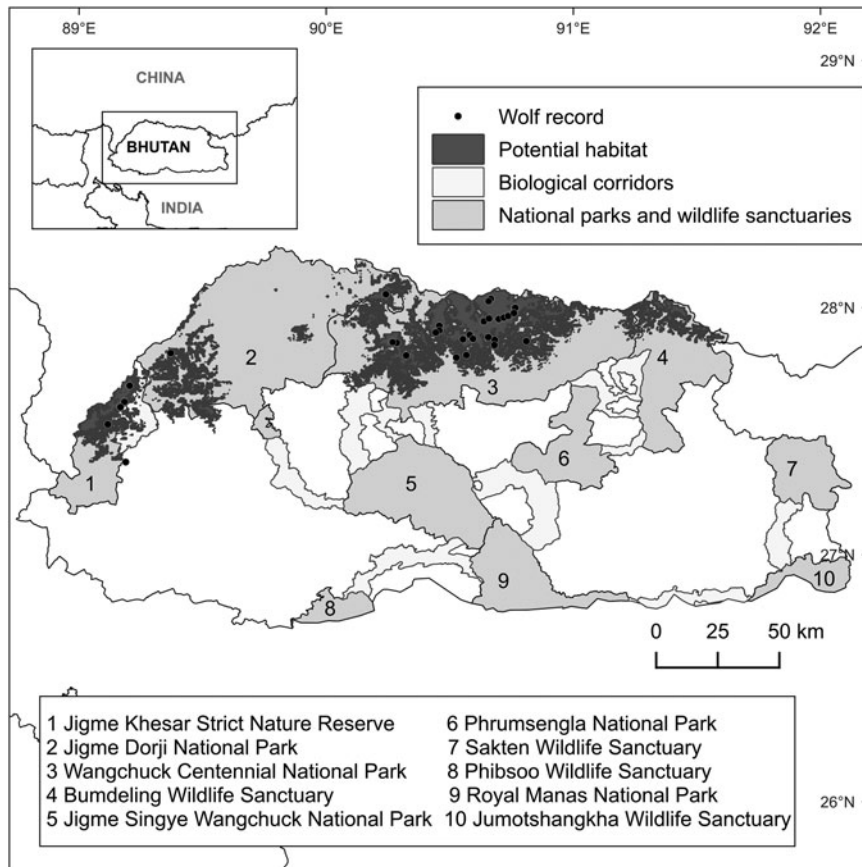
Tᴀʙʟᴇ 1 Relative contributions of four environmental variables to the model of potential habitat for the Himalayan wolf *Canis lupus chanco* in Bhutan (Fig. 1) using *MaxEnt*. We executed a full model with all 23 variables, and variables contributing < 1% were excluded from the final model.

Environmental variable	Description	Contribution (%)
BIO10	Mean temperature of warmest quarter	35.2
BIO7	Temperature annual range (BIO5–BIO6)	31.5
Land cover	Major land-cover types	18.5
BIO14	Precipitation of driest month	14.8

techniques such as DNA metabarcoding of scats would facilitate the identification of prey species and the degree of dependence on domestic livestock. In conclusion, to ensure the long-term survival of the Himalayan wolf, further investigation is needed in Bhutan of its distribution, ecology and abundance Himalayan and of the availability of suitable wild prey.

Author contributions Data analysis: TD; writing: TD with input from all authors.

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