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Distribution of grey wolves *Canis lupus lupus* in the Nepalese Himalaya: implications for conservation management

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Abstract The grey wolf *Canis lupus lupus* is Critically Endangered in Nepal, and is a protected species there. Understanding the species' status and distribution is critical for its conservation in the Nepalese Himalaya. We assessed the distribution of the grey wolf in the Himalayan and Trans-Himalayan regions using data from faecal and camera trap surveys and published data sources. We recorded 40 instances of wolf presence. Using these data we estimated a distribution of 28,553 km², which includes potential as well as known habitat and comprises 73% of the Nepalese Himalaya. There is evidence of recovery of the grey wolf population in Kanchenjunga Conservation Area in the eastern portion of the species' range. A livestock insurance scheme has been shown to be a viable option to reduce retaliatory killing of wolves as a result of livestock depredation. The wolf plays an important ecological role in the Himalaya, and its conservation should not be delayed by the ongoing taxonomic debate about its subspecific status.

Keywords Camera trapping, *Canis lupus*, distribution, faecal survey, genetic data, grey wolf

Supplementary material for this article can be found at <http://dx.doi.org/10.1017/S0030605316000296>.

Wolves *Canis lupus* are resilient and intelligent predators that have adapted and flourished in a range of habitats, from the Arctic tundra to the Arabian deserts,

yet they are locally extinct in parts of their former range (Mech & Boitani, 2010a). In Asia, wolves are distributed across central Asia from the Trans-Himalayan region of India, Nepal and Tibet to the northern parts of Mongolia and the Korean Peninsula (Pocock, 1941). The species is categorized as Least Concern on the IUCN Red List (Mech & Boitani, 2010b) but the subspecies *Canis lupus lupus* (hereafter referred to as the grey wolf) is categorized as Critically Endangered in Nepal and is included on the country's list of protected animals (GoN, 1973; Jnawali et al., 2011). Despite its Critically Endangered status, research on wolf biology in Nepal has been limited (Baral & Shaha, 2008; Jnawali et al., 2011), as have conservation efforts for the species in the Nepalese Himalaya. We studied grey wolf distribution in the region and refined the existing distributional map according to IUCN guidelines, on the basis of landscape characteristics and habitat types.

The Himalayan mountain range spans 1,500 km along an east–west axis, with three complexes: eastern, central and western (Fig. 1). The range encompasses 10 protected areas, two of which (Shey Phoksundo National Park and Annapurna Conservation Area) overlap with the Trans-Himalayan region. The altitudinal range of the protected areas is 2,500–8,848 m. The rugged, high mountain peaks are characterized by barren, subalpine and alpine vegetation, whereas the Trans-Himalayan region is a rain-shadow area with undulating alpine steppes, sparse scattered shrub and barren patches (Jackson, 1996). The major carnivores of the Himalaya are the snow leopard *Panthera uncia*, Eurasian lynx *Lynx lynx* and common leopard *Panthera pardus*, and the major prey species are blue sheep *Pseudois nayaur*, Himalayan tahr *Hemitragus jemlahicus*, Tibetan antelope *Pantholops hodgsonii*, Tibetan gazelle *Procapra picticaudata*, argali *Ovis ammon* and kiang *Equus kiang*. The Tibetan community is the dominant ethnic group in the region.

We employed a multi-pronged approach to gather information on the spatial distribution of the grey wolf in the Nepalese Himalaya. We used camera trap data (Jackson et al., 2005) from the Nepalese Government's flagship long-term monitoring programme, carried out during 2011–2015 in Kanchenjunga Conservation Area (c. 2,035 km²), genetic sequence data from opportunistic faecal surveys carried out in 2011 and 2014 across seven sites (c. 5,947 km²) in the

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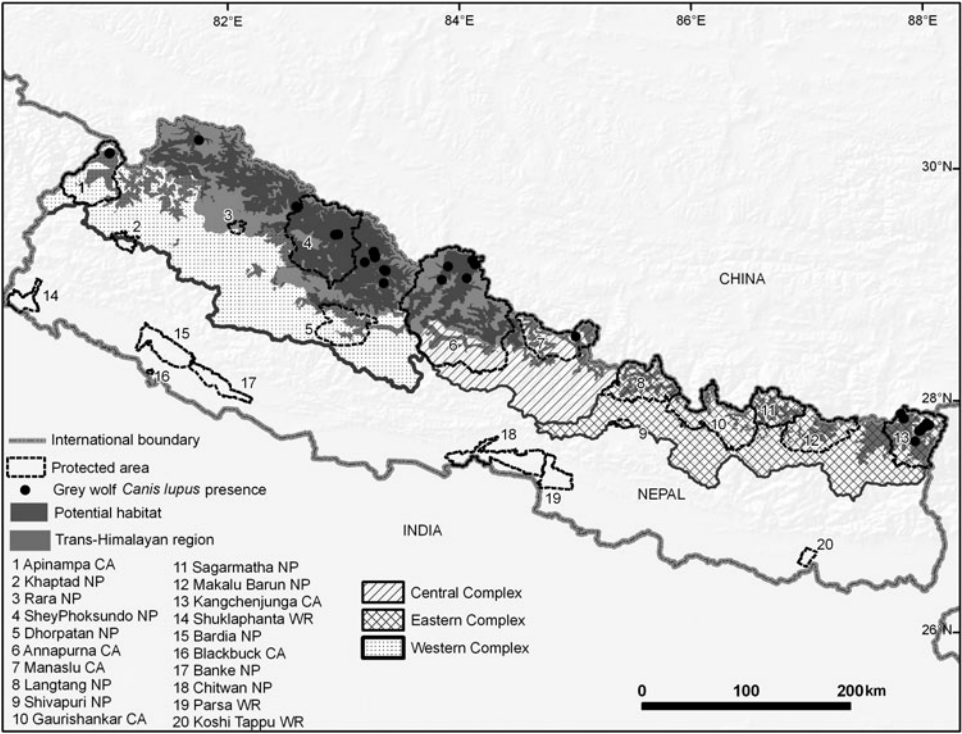


FIG. 1 Potential habitat of the grey wolf *Canis lupus lupus* across the Nepalese Himalaya, modelled using the *MaxEnt* algorithm (Phillips et al., 2006).

TABLE 1 Records of grey wolf *Canis lupus lupus* (n = 40) from a survey conducted in the Nepalese Himalaya (Fig. 1) during 2011–2014, based on faecal samples, direct observation, and camera trap records.

Evidence type	No of records	Location	Study period
Faecal	3	Api Nampa Conservation Area	Apr.–May 2014
Faecal	1	Outside protected area	Apr.–May 2014
Faecal	2	Outside protected areas	Apr.–May 2014
Faecal	18	Shey Phoksundo National Park	Oct.–Nov. 2011 & Apr.–May 2014
Direct sighting	3	Shey Phoksundo National Park; Kanchenjunga Conservation Area	Oct.–Nov. 2011, 23 Nov. 2013
Camera trap	13	Kanchenjunga Conservation Area	Apr.–May 2014 & Nov.–Dec. 2014

western complex (Subba, 2012; WWF, 2015), and published data on the occurrence (n = 8 occurrences) of the grey wolf in the central complex (Acharya & Ghimirey, 2011; Jnawali et al., 2011; Chetri, 2014). We recorded two direct sightings, of three wolves, while surveying in Shey Phoksundo National Park (Subba, 2012). We extracted bioclimatic variables (Hijmans et al., 2005; Phillips et al., 2006) for the spatial data on grey wolf presence to assess potential wolf habitat, and mapped a refined distribution across the Nepalese Himalaya using maximum entropy modelling in *MaxEnt* v. 3.3.1 (Phillips et al., 2006).

A total effort of 3,300 trap nights (Jackson et al., 2005; Alexander et al., 2016) and 154 km of transect surveys yielded 40 records (camera traps, 13; faecal samples, 24; direct sightings, 3) of grey wolves at five sites in the Himalaya (Table 1; Fig. 1; Supplementary Plates S1 & S2). Grey wolves were also

recorded along the high plains bordering Tibet in the Upper Mustang of Annapurna Conservation Area (camera trap; Chetri, 2014), Manaslu Conservation Area (direct sighting), and Dhorpatan Hunting Reserve (Jnawali et al., 2011; Fig. 1). The altitudinal range of grey wolf presence was 3,616–4,950 m. Wolves were recorded primarily in barren areas (40%), followed by alpine grasslands (38%) and alpine shrublands (22%). Sixty-five percent of occurrences were recorded in the Trans-Himalayan region, with the remainder recorded in the Greater Himalayan region. We estimate there is 28,553 km² of potential wolf habitat throughout the Nepalese Himalaya (c. 73%), based on the presence data modelled with bioclimatic variables in *MaxEnt* (Fig. 1). The model output had high discriminative ability (area under curve = 0.973), and the most important contributor was the mean temperature of the coldest quarter (41.1%; Table 2).

TABLE 2 Relative contribution of bioclimatic variables (top five) to the *MaxEnt* model used to map the potential habitat of the grey wolf in the Nepalese Himalaya (Fig. 1).

Bioclimatic variable	Description	% contribution
BIO11	Mean temperature of coldest quarter	41.1
BIO1	Annual mean temperature	18.1
BIO8	Mean temperature of wettest quarter	13.5
BIO6	Minimum temperature of coldest month	7.8
BIO16	Precipitation of wettest quarter	4.7

This was the first extensive study of grey wolves as part of the Nepalese government's snow leopard monitoring programme, and has confirmed their occurrence in the Himalayan and Trans-Himalayan regions. Field observations and previous records indicate a preference for alpine grassland and barren ecosystems, similar to other carnivores such as the snow leopard, Eurasian lynx and common leopard, with distribution across various habitat types. However, wolf distribution in the Churia (Siwalikhs in India) and Lesser Himalaya is unknown.

Wolves were recorded in Kanchenjunga Conservation Area in 2014, whereas they were not recorded by camera-trap surveys there during 2010–2013, indicating that the species may be colonizing this area from Tibet. The subpopulation previously known in Sagarmatha has not been recorded recently (B. Shrestha, pers. comm.). During our preliminary investigation in Kanchenjunga Conservation Area, local people were not supportive of conserving grey wolves as there is no compensation for livestock killed by wolves, as there is for snow leopards (Gurung et al., 2011). Government guidelines for compensating for depredation of livestock did not originally include the grey wolf as a potential predator (GoN, 2012) but the species was added in the first amendment. However, in practice, compensation has not been provided, and therefore retaliatory killing of wolves as a result of human–wolf conflict is a threat to the long-term conservation of wolves in the Himalaya (WWF, 2014).

Another issue of relevance to wolf conservation is the ambiguous taxonomic status of *Canis lupus* in the Himalaya (Shrotriya et al., 2012). The wolves of Nepal are similar to Himalayan wolves of India, having similar morphological features and preferring similar ecological habitats, as evidenced by photographic records from camera traps (Supplementary Plate S2). Genetic studies in the Indian subcontinent have indicated that the wolf populations there are genetically unique, and a distinct species, the Himalayan wolf *Canis himalayensis*, has been proposed (Aggarwal et al., 2007). However, the Himalayan wolf has not been categorized as a distinct species

on the IUCN Red List (IUCN, 2015). Further analysis of genetic data ($n = 21$ samples) has shown evidence of both the Himalayan wolf ($n = 8$) and the Tibetan wolf *Canis lupus chanco* ($n = 13$; WWF, 2015). The taxonomic ambiguity of the Himalayan wolf is a subject for future research but the conservation of this predator should not be delayed until taxonomic issues are resolved using sophisticated techniques (Nowak, 2009).

Multiple studies have highlighted conflict between people and snow leopards (Xu et al., 2008; Wegge et al., 2012) yet have failed to examine conflict with the snow leopard's co-predator, the grey wolf (Namgail et al., 2007; Jumabay-Uulu et al., 2014). We have described the grey wolf's distribution across the Nepalese Himalaya, and identified potential retaliatory killing as a threat to the species' survival. We recommend the establishment of a livestock insurance scheme and the effective implementation of the Government's guidelines for compensation, to discourage retaliatory killing. There is also a need for further investigation of wolf ecology, including its prey species, across the Himalayan landscape to inform action to ensure the long-term survival of this species.

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Contributions

SAS, AKS and KT contributed equally to this article.

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