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# Measuring and mapping the influence of landscape factors on livestock predation by wolves in Mongolia

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ABSTRACT

Gray wolves (*Canis lupus*) are a top predator in northern Asian ecosystems and often perceived as a threat to livestock. As a result, wolves are heavily persecuted and populations have declined throughout much of the region. Understanding the dynamics of wolf-livestock conflict is important for developing conservation actions that benefit wolves and human livelihoods. We measured the influence of landscape factors on patterns of wolf-livestock conflict in Ikh Nart Nature Reserve, Mongolia by modeling livestock predation risk using a partitioned Mahalanobis $D^2$ ($k$) analysis. We based the model on 44 known predation sites obtained through 102 interviews with rural pastoralists and mapped risk at a 500 m spatial scale. Four factors strongly influenced predation risk at a given site in the landscape including distance to nearest ger camp, and the percent of surrounding tall vegetation, shrubland, and forbland habitat. Our results indicate that wolves tend to kill livestock in areas where their detection by humans and livestock is low. Managing wolves in Mongolia will require reducing livestock predation and subsequent retribution killing. This may be achieved by focusing conservation in areas where predation risk is highest, such as habitats with greater vegetation cover and areas near particular ger sites.



## 1. Introduction

Wolves are opportunistic predators (Peterson and Ciucci, 2003; Van Duyne et al., 2009) and historically occurred in every major biome in the Northern Hemisphere populated with large ungulates (Blanco and Cortes, 2009; Fuller et al., 2003). Although wolves typically prefer large wild ungulate prey, they can switch to small- and medium-sized mammals and livestock, particularly when wild ungulate populations decrease (Garrott et al., 2007; Meriggi and Lovari, 1996; Peterson and Ciucci, 2003). Predation on livestock often leads wolves into conflict with humans (Kaczensky et al., 2008; Meriggi and Lovari, 1996; Treves et al., 2004), and wolf-human conflict is frequently considered the single most challenging problem for wolf conservation (Fritts et al., 2003). Identifying causes of conflict and developing conflict mitigation strategies promises to increase conservation success rates (Treves et al., 2004). As modifying human behavior across large areas is difficult, focusing conflict mitigation efforts on areas identified as high risk for conflict offers a more practical approach (Treves et al., 2004).

Wolf-livestock conflict represents a major wildlife management issue in Asia, where wolf populations overlap extensively with livestock husbandry (Hovens et al., 2000; Reading et al., 1998). In Mongolia this is especially true, as wolves represent the most widely distributed large carnivore and the rural human population relies primarily on livestock for subsistence (Clark et al., 2006; Hovens et al., 2000; Kaczensky et al., 2008). Wolf predation on livestock can represent a serious threat to pastoralist livelihoods (Kaczensky et al., 2008; Van Duyne et al., 2009; Wingard and Zahler, 2006). For example, from 2003 to 2005, wolf depredation cost pastoralists in Hustai National Park, a protected area 150 km southwest of Mongolia's capital of Ulaanbaatar, $600–$1900 USD per year (5–11% of total herd value) (Van Duyne et al., 2009).

Rural pastoralists often protect livestock by proactively killing wolves. This traditional practice also has cultural and spiritual importance (Charlier, 2012; Davie et al., unpublished data). However, rates of wolf killing have increased in recent years, especially as vehicles and guns have become more available and affordable to the rural public (Kaczensky et al., 2008; Wingard and Zahler, 2006).

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Relative lack of legal protection for wolves outside of national parks, nature reserves, and other protected areas has increased wolf mortality rates (Boitani, 2003; Hovens et al., 2000). As a result, the wolf population has declined and conservationists listed the species as IUCN Near Threatened in the country (Clark et al., 2006).

Quantifying how different factors in the landscape influence livestock predation risk may help conservationists develop strategies for reducing wolf persecution. For example, studies in North America found that areas of frequent predation contained a consistent set of landscape features (Treves et al., 2004). Modeling these features can help predict predation risk across other landscapes to inform management and decision-making (Edge et al., 2011; Treves et al., 2004). To date few studies have quantified predation risk based on landscape characteristics outside of North America, and many have focused on the influence of prey population trends (wild and domestic), the proximity of protected areas, and animal husbandry practices (Edge et al., 2011; Fritts et al., 2003; Treves et al., 2004; Van Duyne et al., 2009).

In this study, we investigated the influence of landscape characteristics on the probability of wolf predation on livestock in an arid steppe region of Mongolia. Our approach involved collecting data on livestock predation sites, estimating the habitat characteristics at each site, then developing a model describing the influence of these characteristics on predation using a partitioned Mahalanobis $D^2$ ($k$) analysis. We then mapped predation risk across the larger landscape.

## 2. Materials and methods

### 2.1. Study area

We conducted the study in and around Ikh Nart Nature Reserve, Dornogobi Aimag (province), Mongolia (45°43′N, 108°39′E) in 2011 and 2012 (Fig. 1; Reading et al., 2011). Ikh Nart is a 666 $km^2$ protected area established in 1996 to conserve a population of globally important argali sheep (*Ovis ammon*) and the unique landscape of the region (Myagmarsuren, 2000). Wolves occur throughout the region, occupying all major habitat types (Reading et al., 2011). The size of the Ikh Nart wolf population is unknown, but the species appears to occur in densities typical of steppe ecosystems in Mongolia (Fuller et al., 2003; Kaczensky et al., 2008; Wingard and Zahler, 2006). Wolves consume wild species, such as argali sheep and Siberian ibex (*Capra sibirica*), which represent the only two species of wild ungulates that occur in high densities year-round in the reserve (Reading et al., 2011). Wolves also consume livestock, and local pastoralists perceive losses as an important concern for their livelihoods (Davie et al., unpublished data). Over one hundred households live in and around the reserve, and pastoralists raise five species of livestock: goats (*Capra aegragus*), sheep (*Ovis aries*), horses (*Equus ferus caballus*), cattle (*Bos tarus*), and camels (*Camelus bactrianus*).

Ikh Nart topography is variable, consisting of open, gently rolling plains, rugged areas of rocky outcrops, and steep-sided drainages (Reading et al., 2011). Grasses, forbs, and shrubs are the primary vegetation of the plains while rocky areas and drainages often include trees (e.g., elm *Ulmus pumila*, and willow, *Salix ledeubouriana*) and tall vegetation (e.g., needlegrass, *Achnatherum splendens*) (Jackson et al., 2006). Climate is arid, with <200 mm of annual precipitation, and variable, with temperatures ranging from −40 °C to +43 °C.

### 2.2. Livestock predation

We gathered data on the locations of livestock predations within the last year through interviews with pastoralists living in and around the reserve in 2012 (Fig. 1). For our analysis we only considered kill locations that fell within the boundary of our study area as defined by available habitat maps covering 729 $km^2$ in and around the northern half of the reserve (Jackson et al., 2006). Each semi-structured interview lasted from 30 min to 1.5 h in length and was administered by one foreign researcher and one Mongolian researcher, the former responsible for monitoring data consistency across all interviews, and the latter responsible for interpreting and providing cultural context. Interviews included questions on general demographic data, herding methods, predation rates and locations, and pastoralist attitudes towards wolves. Pastoralists identified livestock predators as wolves (rather than domestic dogs, which are trained not to attack livestock) based on tracks, bite and feeding patterns, and observation of wolves at predation sites. Our analysis was based on information obtained from interviewees because actual predation events are relatively infrequent and difficult to observe. As a result, our analyses assumed that wolf kills reported by pastoralists were correctly identified. For each predation site identified by pastoralists, we recorded the location using a handheld Global Positioning System (GPS). We added locations to a Geographic Information System (GIS) (ArcGIS v. 10, ESRI, Redlands, California, USA) for analysis.

### 2.3. Landscape factors

We considered the following landscape factors in our analysis: habitat type, terrain ruggedness, distance to nearest road, and distance to nearest ger site (Table 1). We hypothesized that habitat type was an important predictor of good grazing, and thus livestock density, which could influence patterns of wolf occupancy. We used six habitat types based on classified satellite images (Jackson et al., 2006), including rocky outcrop (rocky substrate with sparse vegetation), shrubland (high density; dominated by peashrubs, *Caragana pygmaea*), shrubland (low density; dominated by wild apricot, *Amydalus pedunculata*), forblands (open plains dominated by *Allium* spp. and other forbs), semi-shrublands (species-diverse open plains dominated by turfy semi-shrubs such as *Reaumuria soongorica* and *Salsola passerina*), and tall vegetation (dominated by tall grass including needlegrass and trees such as willow and elm). We considered terrain ruggedness using slope and aspect layers (Global Land Survey Digital Elevation Model, USGS, 2008, http://www.usgs.gov) as ruggedness surrogates. Studies elsewhere in Mongolia indicated that wolves often use more rugged areas that are generally inaccessible to hunter vehicles (Kaczensky et al., 2008). We calculated distance to ger sites and roads using the point and track locations recorded on a handheld GPS unit during pastoralist interviews. Ger sites and roads represent areas of highest human (and livestock) activity and may act as either an attractant (i.e., higher chance of encountering livestock prey) or deterrent (i.e., higher chance of mortality from pastoralists). Roads were all dirt tracks. Rural pastoralist families primarily reside in gers (portable, felt covered and wood framed homes) that they move seasonally to different sites. We extracted values for all variables from GIS raster and feature class files at four spatial scales, using circular buffers around each kill site with radii of 100 m, 250 m, 500 m and 1000 m. We examined the influence of landscape factors on predation at multiple spatial scales. Predation may be driven by the immediate, fine-scale characteristics of a landscape, such as shrub and grasslands in a drainage bottom. However, it may be better explained by the broader landscape around a kill site that may, for example, also incorporate the rugged, rocky areas surrounding a drainage. We arbitrarily chose four spatial scales that we believed represented a gradient from small-scale to large-scale based on observations of wolves in the study area and our knowledge of the Ikh Nart. We tested all landscape variables for significant correlations ($\alpha = 0.05$) and selected one variable when two or