Biological Conservation 203 (2016) 168–175

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Human activities negatively impact distribution of ungulates in the Mongolian Gobi

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ARTICLE INFO

Article history:
Received 27 February 2016
Received in revised form 8 September 2016
Accepted 14 September 2016
Available online xxxx

Keywords:
Spatial modelling
Equus hemionus
Mining development
Gobi desert
Mongolia
Gazella subgutturosa

ABSTRACT

The Southern Gobi of Mongolia is an iconic ungulate stronghold that supports the world's largest populations of Asiatic wild ass (or khulan – *Equus hemionus*) and goitered gazelle (*Gazella subgutturosa*). A growing human population, intensifying exploitation of natural resources, and the development of infrastructure in the region place increasing pressure on these species and their habitats. During 2012–2015, we studied factors influencing the distribution of these two ungulate species in the Southern Gobi to better inform management. We built Generalized Linear Mixed Models (GLMMs) to predict the location of suitable habitat for the two species using environmental and human-associated factors. These models were validated using independent telemetry data for each species. The GLMMs suggest that the probability of ungulate presence decreased with increasing human influence and increased in areas with intermediate values of elevation and Normalized Difference Vegetation Index (except for goitered gazelle). Notably, human-associated factors were more important than environmental variables in explaining the distribution of the two species. Habitat models predicted between 45 and 55% of the study area to be suitable for khulan and between 50 and 55% suitable for goitered gazelles during 2012–2015. Models for both species had good predictive power, as nearly 90% of khulan and 100% of goitered gazelle telemetry locations from separate data sets were found within the predicted preferred areas. Our approach quantifies the key drivers of their distribution and our findings are useful for policy makers, managers, and industry to plan mitigation measures to reduce the impacts of development.

1. Introduction

The Mongolia's Southern Gobi Desert is among the world's largest and most intact arid rangelands, and thus is of global importance (Batsaikhan et al., 2014). This region supports a unique assemblage of native wildlife, including the largest populations of Asiatic wild ass (or khulan, *Equus hemionus*) and goitered (or black-tailed *Gazella subgutturosa*) gazelle in the world (Buuveibaatar et al., 2016). For both species, poaching is primary driver of population declines throughout their range (Mallon and Zhigang, 2009; Stubbe et al., 2012), although habitat loss and fragmentation across the species' range may also be important (Clark et al., 2006; Ito et al., 2013a; Batsaikhan et al., 2014). The khulan is categorized as Near Threatened (Kaczensky et al., 2015), while goitered gazelles are listed as Vulnerable on the IUCN Red List (Mallon, 2008).

The desert ecosystem is characterized by seasonal extremes of heat and cold, unpredictable precipitation, and accompanying low and dramatically variable pasture productivity (von Wehrden et al., 2012). The overall sparse environment with tremendous interannual variability in high-quality pasture resulted in the development of a nomadic ungulate system. Well-adapted ungulate species in the region survive because of their ability to move long-distances to find suitable habitat (Olson et al., 2010; Kaczensky et al., 2011a). Conservation of this highly dynamic system is particularly challenging because of the large areas required to provide enough pasture for viable populations (Ito et al., 2013b).

The Southern Gobi also is rich in mineral deposits (World Bank, 2006), and a number of mining-related development and infrastructure projects are underway or planned (Walton, 2010; Batsaikhan et al., 2014). As extractive industry developments expand across the region, they disrupt migratory movements, fragment habitat, and cause direct or indirect habitat loss (Ito et al., 2008; Kaczensky et al., 2011a). However, little is known about the impacts of mining development and operations on khulan and goitered gazelles and their habitats. Consequently,

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http://dx.doi.org/10.1016/j.biocon.2016.09.013
0006-3207/

determining key variables influencing distribution of and the amount of potential habitat available to khulan and goitered gazelle in the vast landscape of the Southern Gobi is crucial to policy makers, managers, and industry for developing mitigation measures and planning landscape-level conservation strategies (Kaczensky et al., 2008; Mallon and Zhigang, 2009).

In this manuscript, we present results of statistical analyses using observations of khulan and goitered gazelle group locations, remotely sensed variables, and disturbance indices to produce spatially explicit habitat models for these ungulates. We were particularly interested in determining whether environmental or human associated factors are the main drivers in influencing the distribution and habitat of both species. These results are important for understanding the current drivers of distribution, determining critical habitat for these species, and offering guidance to mitigate impacts from mine and associated infrastructure developments in the region.

2. Material and methods

2.1. Study area

We conducted our study across a 98,216-km^2 area in Mongolia's Southern Gobi (Fig. 1), where elevation ranges from 683 m to 1884 m. Average annual precipitation is 150 mm in the southeast part of the study area, but considerably less (≤100 mm) toward the north and west. The average annual temperature is around 5 °C, but daily means may reach 40 °C in summer and drop to −35 °C in winter. Vegetation is sparse and in many areas is dominated by drought-adapted central Asian desert species, particularly *Artemisia spp*., *Allium spp*., *Stipa spp.,* and *Anabasis brevifolia* (von Wehrden et al., 2012). There are a few tree species, including saxaul (*Haloxylon ammodendron*) and elm (*Ulmus pumila)*, which are confined to the river valleys and basins. Surface water is restricted to springs, some of which are permanent, primarily located in or near mountain ranges. Khulan are capable of accessing water by digging in dry riverbeds where the ground water table is high, thereby also creating temporary water points for other wildlife, including gazelles. In addition to the two study ungulates, there are Mongolian gazelle (*Procapra gutturosa*), argali sheep (*Ovis ammon*) and ibex (*Capra sibirica*) present. Mammalian carnivores include the wolf (*Canis lupus*), lynx (*Lynx lynx*), red fox (*Vulpes vulpes*), and corsac fox (*Vulpes corsac*).

The study area is limited to the south and east by a fenced border with China and by the Trans Mongolian Railroad corridor, respectively, which create nearly impermeable barriers to ungulate movement (Linnell et al., 2016). In addition, two parallel paved roads connecting major mining activities and the Chinese border crossings are present to the west (Fig. 1). There are four protected areas, which comprise approximately 20% of the study area (e.g., 18,949 km^2). Human populations in the region are concentrated in *soums* (villages/towns), with the rural population primarily consisting of semi-nomadic livestock herders. The region is at the center of the cashmere goat industry in Mongolia, and livestock products generate the main income of local herders (Berger et al., 2013).

2.2. Data collection

Each year during 2012–2015, we surveyed of the same 64 transect lines totaling 3464 km of survey effort across the 98,216-km^2 area (Table S1; Fig. 1). The transect lines were randomly located and systematically spaced 20 km apart using the Distance software (Strindberg et al., 2004; Thomas et al., 2010). The survey was conducted using distance sampling line transect approaches (see Buuveibaatar et al., 2016 for details), in accordance with guidelines recommended by Buckland et al. (2001). To develop a habitat suitability model for the two species, the entire length of each transect driven was divided into 724 5 × 5 km blocks. We calculated presence/absence of ungulates in each block to derive a binary response variable. We then selected a set of environmental and human associated covariates for habitat modelling that we hypothesized to be important predictors of the two species based on other studies (Buuveibaatar et al., 2014; Farhadinia et al., 2009; Kaczensky et al., 2008, 2011a). Predictor variables used in the spatial modelling included the Normalized Difference Vegetation Index (NDVI), elevation, slope, distribution of households, human disturbance, and distance to the

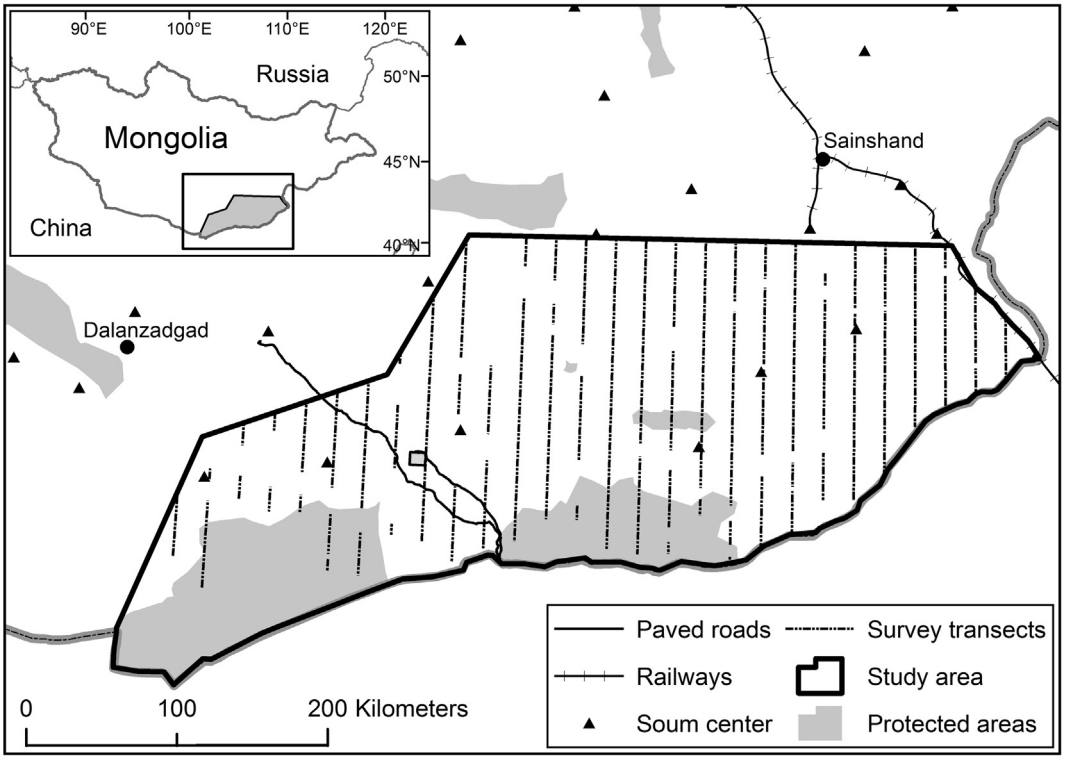

Fig. 1. Study area with survey transects sampled during 2012–2015, in the Southern Gobi, Mongolia.