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Original Investigation

Factors influencing red fox occupancy probability in central Mongolia

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ABSTRACT

The red fox (*Vulpes vulpes*) occurs widely throughout the northern hemisphere, but few models exist to describe the species' distribution, especially in Asia where populations are thought to be declining in part due to habitat loss and conversion. We used an occupancy modeling approach to evaluate how landscape factors influence red fox distribution in a steppe region of Mongolia. We collected detection/non-detection data from four surveys of 124 sites from June to September 2010, then evaluated the support of six models to explain occupancy probability in the landscape. Models related occupancy probability to (1) cover habitat, (2) food-rich habitat, (3) open habitat with greater opportunities for vigilance, (4) human developments including herder camps and roads, and (5) marmot colonies, which provide denning sites. We also included a null model that no factors meaningfully influenced occupancy. We detected foxes at 38 sites (31% of total) and during 54 surveys (11% of total). Only the 'cover' model demonstrated strong empirical support. This model suggested that occupancy probability was positively influenced by the amount of rocky and shrubland habitats, which provide the most cover and concealment. Red foxes are intensively hunted in Mongolia (and elsewhere in Asia) and probably seek these habitats to avoid detection, suggesting that hunting pressure influences patterns of distribution. Our results provide a model that may be applied to other steppe regions to map red fox distribution and explore how landscape changes may affect the species.

Introduction

The way a species uses a landscape reflects its biological needs and the relative costs and benefits of different habitats. Patterns of use may be governed by biotic factors, such as vegetation type and the presence of other species, and abiotic factors, such as soil type and human developments like roads and houses (Morrison et al., 2006). However, estimating the influence of these factors is often challenging, especially for carnivores, which tend to be nocturnal, wary of people, and difficult to detect (Gompper et al., 2006; Long et al., 2007; Zielinski and Kucera, 1995). Common approaches to understanding habitat use involve capturing, marking, and tracking individuals and subsequently building models (e.g., Resource Selection Functions) that describe animal locations or home ranges (Boyce and McDonald, 1999). A less invasive and cost-efficient alternative involves surveying the presence and absence of species across a landscape to draw inferences about species–habitat relationships (MacKenzie et al., 2002). From these data, models can be built that estimate how different factors influence the probability of a species occurring at a given site in a landscape (MacKenzie et al., 2002).

The red fox (*Vulpes vulpes*) represents the widest-ranging terrestrial member of the Carnivora (Macdonald and Reynolds, 2004). Red foxes range across much of North America, Europe, and Asia and occupy an estimated 70 million km^2 (Macdonald and Reynolds, 2004). Red foxes have been well-studied in many parts of their range and generally exhibit a high degree of behavioral flexibility (Larivière and Pasitschniak-Arts, 1996). However, most studies have focused on populations in Europe and North America and many have involved foxes living in urban environments (Baker and Harris, 2004). Red fox populations remain largely unstudied in Asia, where the species occurs in a variety of ecosystems unique to the region such as desert, semi-desert, and grassland steppe (Heptner and Naumov, 1998; Ognev, 1962). The paucity of information on red foxes presents a challenge to wildlife managers because the species is thought to be declining in some countries (e.g., Mongolia) (Clark

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et al., 2006) and possibly extinct in others (e.g., South Korea) (Yu et al., 2012). Declines have been attributed to several causes including over-harvesting, persecution, habitat loss, and disease (Clark et al., 2006; Heptner and Naumov, 1998; Macdonald and Reynolds, 2004). In Mongolia, intensive harvesting for furs and body parts that often enter the illegal wildlife trade represents a major driver of declines in some areas (Wingard and Zahler, 2006).

In this study, we examined how landscape factors influence red fox distribution in an arid region of Mongolia. We used an occupancy modeling approach based on data collected during multiple surveys, then developed six models to explain the probability of a red fox occurring in the landscape based on knowledge of their behavior. Model selection techniques were then used to determine the model with the most empirical support. We also used the results to map red fox occupancy across the study area.

Material and methods

Study area

We conducted the study in Ikh Nart Nature Reserve, Dornogobi Aimag (province), Mongolia (Fig. 1; 45°43′N–108°39′E) (Reading et al., 2011). Ikh Nart covers 666 km^2 and was established to protect a population of argali sheep (*Ovis ammon*) and the arid landscape of the region (Myagmarsuren, 2000). The reserve consists of gently rolling open plains and rugged rocky areas separated by drainages. Open plains are primarily dominated by short grasses, semi-shrubs, and forbs. Rocky areas are sparsely vegetated and composed mainly of rugged hills and outcrops. Drainages in these areas are dry for most of the year and only flow for short periods (i.e., 1–2 days) following heavy rains. Vegetation in drainages includes mainly tall grasses (needlegrass, *Achnatherum splendens*) and occasionally trees. Shrublands also occur throughout the reserve and are dominated by peashrub (*Caragana pygmaea*) and wild apricot (*Amygdalus pedunculata*). The region is arid with <200 mm of annual precipitation and temperatures typically range from −40 °C in winter (December–March) to +40 °C in summer (June–September). Red foxes occur throughout the reserve and have been observed in all major habitats, but seem to favor more rugged rocky areas (Murdoch et al., 2007).

Surveys

We collected information on patterns of red fox occupancy by conducting scat surveys. We conducted four surveys (one survey per month) of 124 sites from June to September 2010. At each site, we marked a 25 m radius circular plot, then searched each plot intensively in a zig-zag pattern for 5 min. We used scat as a measure of presence and recorded whether we detected scat or not at each site during each survey. Preliminary observations indicated that scats represented a reliable measure of presence because they desiccate and slowly decompose in the study region, and thus persist for long periods of time. Tracks represented an alternative measure of presence, but we did not use them as tracks are rarely seen because of the soil conditions and tend to only last for short periods due to windy conditions. We identified red fox scats based on Batsaikhan et al. (2010), and distinguished them from corsac fox (*V. corsac*) scat based on size and shape (for criteria, see: Murdoch et al., 2010a). If we detected a scat, we then removed it from the plot to avoid recounting it during the next survey. Among the sites, 62 were randomly selected and 62 occurred on Siberian marmot (*Marmota sibirica*) colonies to examine the effect colonies may have on occupancy (see below). We randomly selected marmot colony sites from a map of 115 colonies developed in 2009 (S. Buyandelger, unpublished data) and placed surveys at the geometric center of each colony site. All survey sites were separated by a minimum of 0.5 km.

We estimated the percent of four habitats, including rocky outcrop, shrubland, grassland, and open plains surrounding each site. We estimated percentages using a classified satellite image of the study area in a Geographic Information System (ArcGIS 10, ESRI, Redlands, California) (Jackson et al., 2006). We estimated habitat percentages at three spatial scales, including 25 m, 250 m, and 500 m radii circular buffers from the center of each plot. We selected these scales to account for potential landscape influences at micro or macro levels. Spearman's rank correlation indicated significant correlations ($p < 0.05$) between habitats at these scales, so we arbitrarily selected one scale (250 m) to use in our analysis. We also estimated the distance to the nearest herder camp (or ger) site, and nearest road based on maps developed during the study. There were no significant correlations between habitat, ger, and road variables at our selected scale. We recorded the percent vegetation cover at each plot in each survey because of its potential effect on ability to detect scats. We report all site data with ±1 SE.

Models

We developed six models to explain the probability of a red fox occurring at a given site in the landscape (Table 1). Each model represented a hypothesized relationship between occupancy probability and landscape variables. We based these models on previous observations, scat locations, and radio-tracking data in the region (Table 1).

The first model, COVER, stated that occupancy is influenced by the amount of cover habitat that provides refuges from predation (including hunting by humans). The rationale for this model was that two habitats, rocky outcrops and shrublands, appear to provide the greatest degree of cover and protection for the species relative to other habitats. Red foxes face two primary sources of mortality, including humans that often hunt red foxes by vehicle and wolves (*Canis lupus*) that kill red foxes during encounters (Heptner and Naumov, 1998; Murdoch et al., 2010b). If red fox occupancy relates to avoiding these threats, then we expected rocky outcrops and shrublands to positively influence occupancy. Rocky areas are largely inaccessible to vehicles and shrublands probably allow red foxes to better hide and avoid detection by wolves.

The second model, FOOD, stated that occupancy is influenced by the distribution of food resources. Red foxes have a variable diet in Ikh Nart, but consume insects and rodents most frequently and in greatest volume (Murdoch et al., 2010a). Monitoring in the reserve identified one habitat, grassland, as containing much higher densities of insects and rodents relative to other habitats (S. Buyandelger, unpublished data). Grasslands included areas dominated by tall grasses (>1 m in height) such as needlegrass. If red fox occupancy is driven by the abundance of food, then we expected this habitat to have the most effect.

The third model, VIGILANCE, stated that occupancy is influenced by areas that allow for the greatest amount of vigilance against predators and hunters. In Ikh Nart, open plains most likely allow foxes to detect predators and hunters better than other habitats. Open plains are gently rolling and dominated by short vegetation, including short, ground cover grasses, forbs, and semi-shrubs, and allow for an unobscured view of surroundings relative to other habitats. If occupancy is driven by opportunities to be more vigilant, then we expected open plains to be actively selected.

The fourth model, HUMAN, stated that occupancy is influenced by human features in the landscape. Herders live throughout the reserve in gers (i.e., yurts) that are used seasonally and on a yearly basis (Davie et al., 2014b). Approximately 102 ger sites occur in the study area and each site is occupied by a core family that typically includes immediate family members (i.e., spouses, children)