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Land sharing is essential for snow leopard conservation

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ABSTRACT

Conserving large carnivores in an increasingly crowded planet raises difficult challenges. A recurring debate is whether large carnivores can be conserved in human used landscapes (land sharing) or whether they require specially designated areas (land sparing). Here we show that 40% of the 170 protected areas in the global range of the snow leopard (*Panthera uncia*) are smaller than the home range of a single adult male and only 4–13% are large enough for a 90% probability of containing 15 or more adult females. We used data from 16 snow leopards equipped with GPS collars in the Tost Mountains of South Gobi, Mongolia, to calculate home range size and overlap using three different estimators: minimum convex polygons (MCP), kernel utility distributions (Kernel), and local convex hulls (LoCoH). Local convex hull home ranges were smaller and included lower proportions of unused habitats compared to home ranges based on minimum convex polygons and Kernels. Intra-sexual home range overlap was low, especially for adult males, suggesting that snow leopards are territorial. Mean home range size based on the LoCoH estimates was 207 $km^2 \pm 63$ SD for adult males and 124 $km^2 \pm 41$ SD for adult females. Our estimates were 6–44 times larger than earlier estimates based on VHF technology when comparing similar estimators, i.e. MCP. Our study illustrates that protected areas alone will not be able to conserve predators with large home ranges and conservationists and managers should not restrict their efforts to land sparing.

1. Introduction

Maintaining viable populations of large carnivores is a major challenge for biodiversity conservation because carnivore food requirements and extensive spatial needs often conflict with human interests (e.g. Treves and Karanth, 2003). In contemporary conservation planning these challenges are manifested in two paradigms, the "coexistence" (land sharing) and the "separation" (land sparing) models (Fischer et al., 2014; Chapron et al., 2014). Both approaches face considerable challenges; land sharing requires human activities to be tolerant enough towards biodiversity, including species that pose a risk to life or property (e.g. livestock), whereas land sparing requires large enough areas to be set aside exclusively for conservation. Although large carnivores can persist in human-dominated landscapes when attitudes and policies are favorable (Linnell et al., 2001; Chapron et al., 2014), challenges posed by conflicts associated with livestock killing, competition for game animals and attacks on humans must be addressed to ensure long-term coexistence (Inskip et al., 2009; Johansson et al., 2015). For land sparing, the size of the protected areas is a key predictor of success in conserving large carnivore populations (Balme et al., 2010; Woodroffe and Ginsberg, 1998). However, land sparing may be inefficient (Liu et al., 2001; Rauset et al., 2016) or not possible when land is expensive or when human exclusion has substantial negative impacts on affected people (Schmidt Soltau, 2003; Bauer et al., 2015).

The relative emphasis needed on either approach for conserving a target species largely depends on the species' spatial requirements and social organization. This is because long-term population viability will be determined by: (1) the key drivers of population growth (survival and fecundity), which are a function of habitat quality, including human factors, and (2) stochastic population extinction risk, which will be a function of population size (Caswell, 2000). Thus, key parameters in predicting the size and location of adequate spared land for maintaining viable populations of a target species are its home range size,

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territoriality, and habitat suitability. In most solitary carnivores, males have larger home ranges than females (Sandell, 1989), and it is therefore necessary to estimate sex-specific home range sizes. Similarly, home ranges can be overlapping or exclusive, which can strongly influence how many individuals occupy an area. Understanding home range size and social organization is critical for predicting the number of animals that can be sustained within conservation areas, and thus for predicting long-term population viability (Balme et al., 2010; Woodroffe and Ginsberg, 2000). Animals with small and overlapping home ranges will require less land than animals with large and/or non-overlapping home ranges. Home range use is also related to habitat quality which is an important determinant of survival and reproduction (Schwartz et al., 2006). With advances in animal tracking technology, it has now become possible to obtain relevant data to understand the spatial ecology of large carnivores and feed the information into conservation planning (Schwartz et al., 2006; Balme et al., 2010).

Snow leopard (*Panthera uncia*) distribution spans 1.2–1.6 million km^2 of high mountain habitat in 12 countries of central Asia (Jackson et al., 2010). Snow leopards primarily share the landscape with livestock herders and only a small proportion of the species' range (14–19%) is set aside in protected areas (Deguignet et al., 2014). The snow leopard is classified as endangered by IUCN, where the main threats to the species are retaliatory killing in response to livestock predation, poaching for trade in fur and bones, depletion of wild prey, and habitat degradation and fragmentation resulting from mining and development (Jackson et al., 2008, 2010). It is not clear how effective protected areas are for snow leopard conservation because published information on snow leopard spatial ecology is limited to three studies (Jackson, 1996; Oli, 1997; McCarthy et al., 2005) that were all based on few individuals ($n = 3$–5) equipped with VHF collars. The information obtained from VHF collars may not be adequate for snow leopards, as preliminary information from studies using Global Positioning System (GPS) technology in three different countries (Afghanistan, Pakistan and Mongolia) suggests that snow leopard home ranges may be substantially larger than earlier studies have reported (Johansson et al., 2016). To better assess the scale and land tenure (sharing vs. sparing) where conservation efforts need to be focused, it is critical to obtain accurate information on the spatial requirements and social organization of snow leopards.

To achieve this goal we fitted snow leopards of both sexes with GPS collars in Tost, a mountain range in southern Mongolia that was declared as State Reserve in 2016 but was a multiple use area during data collection for this manuscript. Our aims were to (1) generate robust and biologically relevant estimates of sex-specific home range size for snow leopards, (2) estimate the extent of home range overlap for neighbouring individuals to examine territoriality, and (3) compare the size of protected areas throughout the snow leopard range with the home range size of adult snow leopards to assess if snow leopard conservation can rely on current protected areas or if a land sharing approach is required to conserve the species.

2. Materials and methods

2.1. Study area

The study was conducted in the Tost Mountains in the Gobi Desert of southern Mongolia (43°N, 100°E, Fig. 1). The area consists of several mountain massifs, crisscrossed by canyons and steep ravines. The mountains gradually shift from steep cliffs in the centre to more gentle hills in the periphery followed by steppe, with an altitude range between 1600 m and 2500 m above mean sea level. Annual precipitation is <130 mm/year and expected min and max temperatures are −35 °C to 38 °C with strong winds year around. The snow leopard population in Tost has been estimated to be 10–14 adult individuals (Sharma et al., 2014). Approximately 90 semi-nomadic herder families live in the mountains and surrounding areas; their livestock comprise of goats (*Capra aegagrus hircus*), sheep (*Ovis aries*), camels (*Camelus bactrianus*) and horses (*Equus ferus caballus*). The snow leopards prey mainly on Siberian ibex (*Capra sibirica*), domestic goats and argali sheep (*Ovis ammon*) (Johansson et al., 2015).

2.2. Data collection and study animals

Snow leopards were captured in foot snares set at marking sites and immobilized with a combination of medetomidine and tiletamine-zolazepam (see Johansson et al., 2013 for details of capture procedures). They were equipped with GPS collars (North Star, King George, Virginia, USA, 2008–2009 or GPS-Plus, Vectronic Aerospace, Berlin, Germany, 2010–2014). The North Star and Vectronic collars were programmed to take a GPS fix every 7 and 5 h respectively. We include information from only those snow leopards that were followed for more than

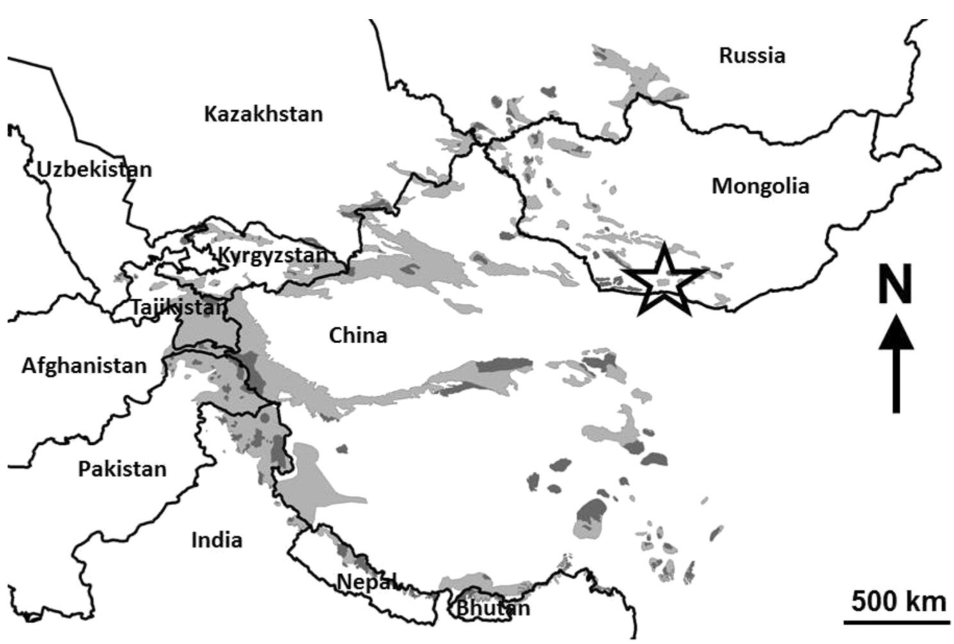

Fig. 1. The global snow leopard (*Panthera uncia*) distribution classified as definite or probable occurrence (light grey; McCarthy et al., 2016), protected areas in snow leopard habitat (dark grey; Deguignet et al., 2014) and the location of the study area (star) in Tost Mountains in the Gobi desert of southern Mongolia.