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Impacts of future climate and land cover changes on threatened mammals in the semi-arid Chinese Altai Mountains

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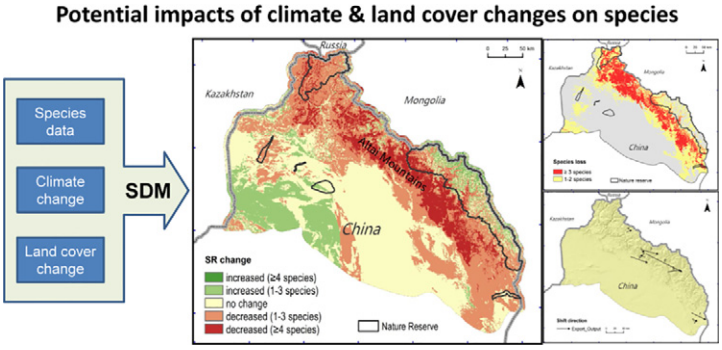
HIGHLIGHTS

- The semi-arid Altai Mountains are undergoing severe environmental changes.
- Species distribution modeling was used to predict range shifts of threatened mammals.
- Abrupt species range shifts are predicted under future climate & land cover changes.
- Remarkable declines in species assemblage and high rates of turnover are predicted.
- Expanding current reserve network and cross-border migration pathways are needed.

GRAPHICAL ABSTRACT



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ABSTRACT

Dryland biodiversity plays important roles in the fight against desertification and poverty, but is highly vulnerable to the impacts of environmental change. However, little research has been conducted on dual pressure from climate and land cover changes on biodiversity in arid and semi-arid environments. Concequntly, it is crutial to understand the potential impacts of future climate and land cover changes on dryland biodiversity. Here, using the Chinese Altai Mountains as a case study area, we predicted the future spatial distributions and local assemblages of nine threatened mammal species under projected climate and land cover change scenarios for the period 2010–2050. The results show that remarkable declines in mammal species richness as well as high rates of species turnover are seen to occur across large areas in the Chinese Altai Mountains, highlighting an urgent need for developing protection strategies for areas outside of current nature reserve network. The selected mammals are predicted to lose more than 50% of their current ranges on average, which is much higher than species' range gains (around 15%) under future climate and land cover changes. Most of the species are predicted to contract their ranges while moving eastwards and to higher altitudes, raising the need for establishing cross-border migration pathways for species. Furthermore, the inclusion of land cover changes had notable effects on projected range shifts of individual species under climate changes, demonstrating that land cover changes should be incorporated into the assessment of future climate impacts to facilitate biodiversity conservation in arid and semi-arid environments.

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1. Introduction

Climate change has been regarded as one of the major threats to biodiversity and ecosystems (Hansen et al., 2001; Travis, 2003). It can severely alter habitats and food sources for wildlife (Stenseth et al., 2002; Thomas et al., 2004) as well as the structure and function of ecosystems (Hughes, 2000; Parmesan and Yohe, 2003). Although many species are expected to shift their range boundaries in response to climate change (Davis and Shaw, 2001; Walther, 2010), there are fears that climate change is happening too fast for some species to adapt, thus ultimately leading to their extinction (Saxon et al., 2005). In addition to climate change, land cover change and its associated habitat fragmentation can also alter biological processes severely and decrease the quantity and quality of habitats (Fahrig, 2003; Root et al., 2003), thereby reducing opportunities for species to adapt, particularly the ability of species to relocate to more suitable habitats (Oliver et al., 2015; Pereira et al., 2012). Previous studies exploring species' responses to climate change have largely disregarded the role of landscape characteristics by assuming that species are limited only by the shift of climatic conditions (Currie, 2001; Roy et al., 2008). An implication of the lack of integrated analysis is that the potential effects of either climate change or land cover change per se are likely to be either over- or under-estimated (Chazal and Rounsevell, 2009). As regional land cover change may exacerbate or alleviate climatic impacts on biodiversity, it is important to integrate both factors to better understand potential impacts of future climate and land cover changes on biodiversity (Mcmahon et al., 2011).

Being central to the well-being and development of millions of people, dryland ecosystems play critical roles in the fight against desertification, climate change, and global poverty (Huang et al., 2016; Safriel and Tal, 2009). On the other hand, biodiversity in arid and semi-arid regions are highly vulnerable to environmental change, because many species already exist at the climatic and water thresholds for survival (Davies et al., 2012; Lioubimtseva et al., 2005). Projected future global warming may further exacerbate water scarcity, making the preservation of these fragile ecosystems even more challenging (IPCC, 2014b; Thomas et al., 2004). Improved knowledge of how dryland biodiversity reacts to climate change and its different levels of response to ongoing environmental change is of critical importance for preserving dryland ecosystems (Willis and Bhagwat, 2009). Developing proactive conservation plan for biodiversity requires accurate predictions of biological responses to potential environmental changes, the extent of expected change as well as the nature of habitat transformations under future climatic and land cover changes (Dawson and Mace, 2011). However, little research has been conducted on the impacts of climate and land cover change in arid environments. The lack of knowledge on how biodiversity would respond to these combined environmental changes greatly hamper the planning and implementation of sustainable biodiversity conservation in the context of climate change (Davies et al., 2012; Lioubimtseva et al., 2005).

The Altai Mountains are an extensive mountain range in arid central Asia, at the intersection of China, Russia, Mongolia and Kazakhstan. As part of the Altai-Sayan Ecoregion (one of the WWF's Global 200 Ecoregions), the Altai Mountains and their associated wetland ecosystems are well known for its unique biological and cultural diversity, and have provided critical ecosystem services such as regional water supply and climate regulation in arid central Asia (Kokorin et al., 2001; Olson et al., 2001). However, this mountainous region, especially the part within China, has received little attention to date (Lioubimtseva and Cole, 2006). Currently, only a Russian national strategy and a Mongolian government action plan for the conservation of Ibis (*Capra sibirica*) and Argali (*Ovis ammon*) have been developed, whereas no such efforts have been made within the Chinese part (WWF, 2010). As the dry southern part of the mountains, the Chinese Altai Mountains is situated in the northern part of Xinjiang Uygur Autonomous Region of China, in which semi-arid biodiversity is greatly threatened by natural and human-induced pressures including land degradation, livestock overgrazing, agriculture development, and climate change (Liu et al., 2002; Zhang et al., 2015). It has been reported that the annual average and maximum temperatures over this region for the period of 2000–2008 raised 3.34 °C and 7.02 °C respectively as compared to the period of 1957–1966 (Aizen et al., 2010). Such increase in temperature results in increased evaporation, which in turn changes vegetation through desiccation and with shifts in species composition (An et al., 2003; Li et al., 2006). It is thus crucial to understand how biodiversity would respond to future climate and land cover changes and develop effective conservation strategies in the context of climate change mitigation in the semi-arid Altai Mountains.

Using target groups of focal species to determine the status of biodiversity is a potential tool to design and assess conservation strategies. These species should be sensitive to environmental change and sampled efficiently in order to yield objective results (Moreno, 2007). Threatened and endangered mammal species are considered good indicators of climate change and land cover change effects on biodiversity, being characterized by narrow range shifts thereby limiting their adjusting to climate change (Hetem et al., 2014). Furthermore, if range shifts are likely to be the dominant species' response to future climate change, then spatially explicit planning will be fundamental to estimating the rate and direction of species displacements required to ensure retention of sufficient range for their future persistence (Midgley et al., 2003), and the analyses must be relevant at regional or sub-regional scales at which most practical conservation decisions are made.

In this study, we aim to assess regional impacts of climate and land cover changes on the future distribution of threatened mammal species in the semi-arid Chinese Altai Mountains. Using species distribution models, we simulated future distributions of these species based on the scenario data of climate and land cover changes, and analyzed its biological impacts by comparing species' current and future distributions under different assumptions of environmental change. This will allow the identification of future suitable habitats for threatened species and help inform priorities for regional conservation planning and biodiversity management in the semi-arid Altai Mountains.

2. Materials and methods

2.1. Study area and selected species

The study area is the southern part of the Altai Mountains (44°59′–49°20′N, 84°30′–90°57′E) that located in northern part of Xinjiang Uygur Autonomous Region of China (Fig. 1), with a total land area of 80,355 km^2. With a typically continental climate, annual average temperatures in this semi-arid region are between −4 °C and 3 °C, with the lowest and highest recorded temperatures being −51.5 °C and 41 °C, respectively; while annual precipitation, which mainly falls as snow, ranges from <100 mm on the plains to >600 mm on the high pastures (Li et al., 2012). The highest areas, following the ridgeline of the Chinese Altai Mountains, are comprised of alpine grasslands and wetland, while the vegetation in the mid-level altitudes includes more hemi-boreal forests with Siberian larch (*Larix sibirica*), Siberian pine (*Pinus sibirica*), and Siberian fir (*Abies sibirica*) (Chen and Yuan, 1989); to the south and west of the mountains, the habitat transitions into lower foothills with shrub cover and grassland; moving down and away from the mountains, the dominant habitat becomes arid and semi-arid steppe, dissected by the Ertix and Ulungur Rivers and their tributaries. The study area harbors 1378 species of flowering plants, 222 birds, and 54 mammals (Olson et al., 2001), including many valuable species for global biodiversity conservation. Currently there are six national and provincial level natural reserves, which cover around 13.6% of the land area.

In consideration of species popularity and data availability, the following locally rare and endangered mammal species were selected for study: Eurasian beaver (*Castor fiber*), Snow leopard (*Panthera unicia*), *Capra ibex* (*Capra sibirica*), Sable (*Martes zibellina*), Manul (*Otocolobus manul*), Moose (*Alces alces*), Argali (*Ovis ammon*), Red deer (*Cervus elaphus*), and Brown bear (*Ursus arctos*). These mammals are known