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Nature reserve requirements for landscape-dependent ungulates: The case of endangered takin (*Budorcas taxicolor*) in Southwestern China

Tianpei Guan [a], Fang Wang [b,c], Sheng Li [c,*], William J. McShea [b]

[a] Ecological Security and Protection Key Laboratory of Sichuan Province, Mianyang Normal University, Mianyang 621000, China
[b] Conservation Ecology Center, Smithsonian Conservation Biology Institute, National Zoological Park, 1500 Remount RD, Front Royal, VA 22630, USA
[c] School of Life Sciences, Peking University, 5 Yiheyuan RD, Beijing 100871, China

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ABSTRACT

Large ungulates commonly perform seasonal or annual movements that encompass considerable land area and various habitat types. Effective conservation of these species relies not only on insights on their basic ecology, but also an understanding on their requirements to move across landscapes. To determine the key landscape characteristics of the endangered takin (*Budorcas taxicolor*), we systematically surveyed for their occurrence in the Northern MinShan Mountains, China, during 2010–2011. We then modeled takin distribution at a regional scale using autologistic regression models, and produced a predictive map for their distribution. The results showed that occurrence probabilities for takin were higher in areas with a larger range of elevation, closer to protected areas, farther from townships, and with more forest coverage. There was a considerable overlap between highly suitable takin habitat and the network of protected forest formed by nature reserves originally established to conserve giant panda (*Ailuropoda melanoleuca*). A broad elevation gradient and the protected area network were essential landscape characteristics in predicting takin distributions and our results suggested that takin should be considered landscape- and conservation-dependent species. The results of this study are applicable to the conservation of large ungulates throughout the mountains bordering the Tibetan Plateau and to a broader suite of mammals that conduct seasonal migrations.

1. Introduction

Many ungulates are characterized by large body size (Fritz and Loison, 2006), highly social behaviors and organization (Schmidt and Gorn, 2013), and a vulnerability to human disturbance (Laurian et al., 2012). Many large ungulates complete seasonal or annual migrations, which may encompass considerable land area and multiple habitat types (Leimgruber et al., 2001; Mueller et al., 2011). These migrations can be across either long geographical distances (e.g., caribou *Rangifer tarandus*, Berger et al., 2006) or elevation gradients (e.g., red deer *Cervus elaphus*, Mysterud et al., 2001). The scale of these movements is larger for species living in non-tropical and/or mountain environments, which are characterized by distinct seasonality and significant heterogeneity in resource distribution (Jay-Robert et al., 2008). Impeding these migrations may result in dramatic population declines (Wegmann et al., 2014). Effective conservation of large ungulates therefore relies not only on insights into their basic ecology, but also an understanding on their requirements to move across a landscape (Mueller et al., 2011; Singh et al., 2012).

Whereas most studies have concentrated on movements across open landscapes (Mose et al., 2013; Owen-Smith, 2014), vertical migrations may be just as essential for a species' persistence. For the large ungulates living in temperate mountain ecosystems, two mechanisms may account for vertical migrations between seasons: either to pursue available food resources (e.g., newly emerged plant leaves in spring) whose phenology results in a limited time of accessibility along an elevational gradient (Zeng et al., 2010), or to avoid the detrimental season features of specific habitats (e.g., deep snow at higher elevation during winter, Gilbert et al., 1970; or insect harassment along low elevation water sources during summer, Downes et al., 1986). The current focus on preserving migration routes between protected areas (Sawyer et al., 2009) should not preclude land managers from assessing vertical migrations within their reserve. For some large ungulates in mountain terrain, vertical corridors within reserves may prove as crucial as movement corridors between protected areas (Herrero et al., 2012; Zweifel-Schielly et al., 2009).

* Corresponding author. Tel.: +86 13811177942.
E-mail address: shengli@pku.edu.cn (S. Li).

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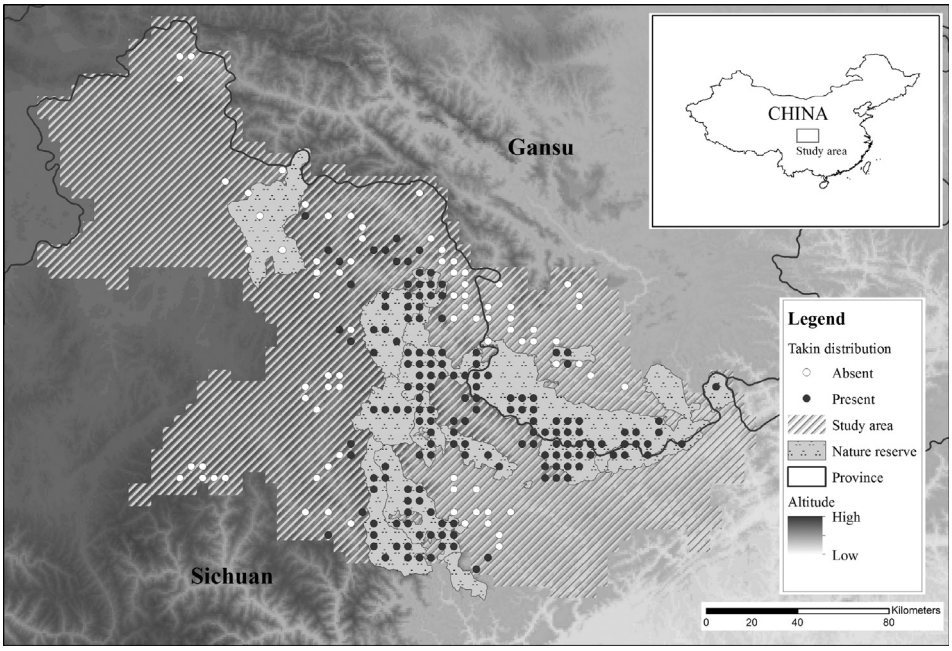

Fig. 1. Study region of takin distribution survey and results of field investigation in Northern MinShan Mountains, Sichuan Province and Gansu Province, China (white = absent and $n = 81$; black = present and $n = 162$).

Takin (*Budorcas taxicolor*) is a large (250–500 kg) and endangered mountain ungulate distributed along the eastern edge of Tibetan Plateau and Himalayas (IUCN, 2014). In China, takin are considered to occupy the mountains of five provinces along the edge of the Tibetan Plateau (State Forestry Administration, 2009; Smith et al., 2010), but their distribution and population status has not been quantified outside of protected areas. Although takin populations are assumed to be decreasing across China (IUCN, 2014), neither sound population estimation nor systematic monitoring has been accomplished at either the reserve or country level. As a herbivore species with a large annual home range (25–98 km^2, Song et al., 2000; Guan et al., 2013) that often encompasses a broad elevation range (1200–3200 m, Guan et al., 2013), takin are a model ungulate that potentially requires specific landscape characteristics. The few studies of takin have been conducted in single reserves with rugged terrain and dense forest cover (Zeng et al., 2003), where they were found to inhabit alpine meadows (2800–3200 m) in summer (June–August), low valley forests (1200–1400 m) in the spring (April–May) and autumn (September–October), and intermediate elevation forest during winter (November–March)(Zeng et al., 2008; Guan et al., 2012, 2013). We lack information on their abundance outside of reserves or beyond the two reserves used in recent studies (i.e., Tangjiahe and Foping nature Reserves).

Meanwhile, our knowledge of takin landscape requirements is limited, which impedes the development of a regional conservation policy. Although numerous nature reserves have been established across their distribution range, none specifically target takin conservation. A cursory examination of species lists for reserves across Sichuan Province indicates they occupy <1/3 of the nature reserves (State Forestry Administration, 2006). Without understanding the landscape requirements of this large ungulate, the effectiveness of these reserves on conserving takin population remains haphazard.

The goal of our study was to determine which landscape, anthropogenic or habitat characteristics influence the occurrence of takin across a mountainous region of Sichuan Province. Our objectives were to: (1) map the distribution of takin at a regional scale using species distribution modeling, (2) identify the key characteristics determining takin distribution, and (3) provide recommendations and guidelines to future conservation planning and management strategies of takin. The results of this study will have strong implications to the conservation of large ungulates in China and elsewhere that conduct seasonal migrations.

2. Study area

We used portions of the northern MinShan Mountains (hereafter referred to as MinShan) as our study area; it is located on the northern flank of a biodiversity hotspot with global significance (Myers et al., 2000; Mittermeier et al., 2005). The MinShan harbors one of the largest continuous habitat patches for takin distributed in China (Smith et al., 2010). Our field investigation was conducted in six counties (five counties in Sichuan Province and one in Gansu Province) during 2010 and 2011, encompassing an area of 38,000 km^2 (102°10′–105°38′E, 31°59′–34°18′) (Fig. 1). The elevation range of our study area is 450–5588 m, and the major vegetation types (usually distributed within elevation bands) are alpine meadow (>3200 m), conifer forest (2800–3200 m), conifer-deciduous mixed forest (2400–2800 m), broadleaf forest (<2400 m) and early successional fields or agriculture along river valleys (typically <1600 m) (Li et al., 2012). Within the study area a network of 16 nature reserves (Appendix A) has been established since the early 1960s and protects 13% of this region. The Minshan area is contiguous with additional nature reserves which partially overlapped our study area, but we will only include in the analysis reserves wholly within the study area. Although most of these reserves ($n = 13$) were originally established and managed for the conservation of the giant panda (*Ailuropoda melanoleuca*), takin occur in several of these reserves. Information on takin (e.g., locations and dates of direct sightings and feces) has been collected during each reserve's annual monitoring activities (described in Gu et al., 2003).