Shared resources between giant panda and sympatric wild and domestic mammals

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ABSTRACT

Interactions between sympatric species may negatively affect a species' fitness, and complicate management of species assemblages in protected areas. An example of the need to quantify the strength and direction of the species interactions is giant panda conservation in newly established reserves. Although the habitat requirements of giant panda have been broadly studied, the degree of its interactions with sympatric large mammals remains unclear. In this paper, we systematically surveyed for species occurrence in the southwestern China during 2008–2013, to better understand the interactions between giant panda and four sympatric large mammal species. We constructed species-specific occupancy models based on camera-trapping data using both environmental and detection variables. We then used the important predictor variables for each species to construct pairwise species co-occurrence models following a Bayesian framework. Our analysis detected significant habitat overlap between giant panda and its sympatric species. However, there was no evidence of native species limiting the distribution of giant pandas despite their extensive use of the same forests. The only evidence for negative interactions was between the distributions of giant panda and domestic cattle within bamboo forest, the primary habitat of giant pandas. The co-occurrence model has value for any conservation planning that benefits from knowledge of inter-species interactions. Our study suggests that, in southwestern China, strict grazing control of domestic cattle in protected areas is warranted until the nature of its interactions with native large mammals can be determined.

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1. Introduction

The interactions between species, either within or between taxonomic groups, play a significant role in structuring animal communities and can range from mutually beneficial (Arnan et al., 2011; Ovaskainen et al., 2010) through neutral (Arnan et al., 2011) to mutually harmful (Pollock et al., 2014). For species of similar body size and foraging strategies, interactions may lower the fitness of at least one species in the dyad (Acebes et al., 2012; Waddle et al., 2010). For example, in the deserts of Argentina, the increased density of domestic donkeys (*Equus asinus*) had a negative impact on the distribution and abundance of guanacos (*Lama guanicoe*), a finding which led to recommended management policies for controlling domestic equids (Acebes et al., 2012). Sites occupied by invasive tree frogs (*Osteopilus septentrionalis*) in Florida reduced the probability of occupancy for 2 native species, *Hyla cinerea* (9 times less likely) and *Hyla*

Squirella (15 times less likely), indicating these species interactions influenced the community assemblage (Waddle et al., 2010). By measuring the proportion of species' pairs that do not co-occur in sets of communities, Kamilar and Ledogar (2011) found that primate communities are not randomly structured and may be the result of interspecific competition. If endangered animals interact with sympatric species, knowledge on the strength and direction of these interactions is important for conservation planning (Acebes et al., 2012; Angelini et al., 2011).

The giant panda (*Ailuropoda melanoleuca*) is an endangered species distributed in approximately 24 habitat patches among six mountain ranges in China (State Forestry Administration, 2006). Giant pandas share distribution with multiple large mammal species whose ranges are broader and often whose local populations are higher in numbers, such as takin (*Budorcas taxicolor*), Asiatic black bear (*Ursus thibetanus*), wild boar (*Sus scrofa*), and domestic cattle (*Bos taurus*) (IUCN, 2000). While the habitat requirements of giant panda have been well studied during the past decades (Liu et al., 2005; Wei et al., 1995; Zhang et al., 2011), the degree to which other large mammal impact giant panda remains unclear.

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The annual giant panda monitoring conducted by nature reserves has revealed several dramatic population declines or distribution shifts in some reserves; some of which were speculated to be the consequences of species' interactions. For example, the avoidance of takin was given as the most probable explanation for the reduced abundance of giant pandas in Tangjiahe Nature Reserve (Wan et al., 2005). Takin and goral (*Naemorhedus griseus*) have been considered "competitive species" due to their heavy consumption of bamboo leaves, while Asiatic black bear and wild boar are believed to alter giant panda habitat selection through their foraging on bamboo shoots (Gong et al., 2006). Ran et al. (2002a) speculated that resource competition and habitat overlap caused livestock to negatively affect giant panda distribution in both the Xiangling and Liangshan Mountains. Hull et al. (2014b) reported domestic horse distributions overlap with suitable giant panda habitat, and speculated that bamboo consumption by horses may have caused observed population declines of giant panda. However, most discussions are speculative (Gong et al., 2006; Wan et al., 2005), or based on indirect evidence from each species' habitat selection (Hull et al., 2014b; Ran et al., 2002a,b).

Quantifying the strength and direction of the interactions between giant panda and sympatric species (both inter- and intra-guild) requires co-occurrence analysis (MacKenzie et al., 2004; Pollock et al., 2014). The presence–absence matrices of any two species inevitably involve multiple factors (e.g., habitat preferences, physiological tolerances, and detection probabilities), some of which are likely to create non-random patterns of species co-occurrence that merely reflect dissimilar habitat preferences instead of actual interactions between the species (MacKenzie et al., 2004; Miller et al., 2012). To differentiate between similar covariate responses and species avoidance or attraction, co-occurrence models provide a powerful tool for constructing interaction models by accounting for species-specific detection probabilities and habitat preferences, as well as species interactions (Gotelli and Ulrich, 2010).

The purpose of this study was to examine the interactions between giant pandas and sympatric large-bodied herbivores (takin, wild boar, and domestic cattle) and the only other ursid species sharing the same habitat (Asiatic black bears). As the reserve system in this region of China was established to conserve giant pandas, which remain at low population densities, our focus was the impact of the more abundant species on giant panda distribution, and not on how the presence of giant panda might impact other species. Our objectives were to use the knowledge on species associations to guide conservation planning for giant panda by: (1) quantify associations in forest landscapes for select sympatric species in southwestern China, and (2) introduce a Bayesian framework for species co-occurrence models. Using this large mammal community as an example, we present a hierarchical approach for modelling interactions between species with variable landscape affinities and detection probabilities.

2. Material and method

2.1. Study area

We used portions of forest habitat among three mountain ranges (Qinling, Minshan, and Qionglai Mountains) as our study area (Fig. 1). These three mountain ranges harbor approximately 89% of the wild giant panda population (State Forestry Administration, 2006), and are within a biodiversity hotspot of global significance (Myers et al., 2000). The study area has a rugged terrain with a broad elevation range varying from 1190 to 4450 m. The original forest composition along the elevation gradient (from low to high) is early successional fields, broadleaf forest,

conifer-deciduous mixed forest, and conifer forest (Tang and Ohsawa, 2002; Zhang, 2001). The landscapes have been significantly altered by agriculture, commercial logging, highway construction, and other human activities in the past decades (Loucks et al., 2001).

2.2. Sampling design and data collection

Our field investigations were conducted in and around eight nature reserves (Wanglang, Wolong, Tangjiahe, Changqing, Huangbaiyuan, Niuweihe, Xiaohegou, and Laohegou Nature Reserves) in Sichuan and Shaanxi Province (102.89°–107.67° E, 30.81°–33.82° N, Fig. 1) from March 2008 through March 2013. We created 1×1 km^2 sampling grids in and around these eight reserves, and conducted camera-trapping surveys in selected cells (see Li et al., 2010a, 2012, and Wang et al., 2014 for details). At the beginning of each sampling period, we randomly selected grid cells and placed one survey location in each selected grid cell at the best location that was identified by field staff. Cameras (CamTrakker™ Digital Ranger or Reconyx™ PC800/900) were mounted on trees at 40 cm height and operated 24 h per day with a 20 s delay between sequential photographs. Most camera stations were baited with commercial carnivore scent lure (Carman's Magna-Glan Lure, Montgomery Fur Company, UT, USA) upon deployment to slow animal movement around the camera to ensure sufficient reaction time for the camera sensor (Barea-Azcón et al., 2007; Crooks, 2002). At the end of each survey period (30–50 days, mean 36 days), the digital flash cards were collected, and the cameras were moved to the next survey locations (Li et al., 2012).

For environmental variables, we reviewed previous habitat studies for each target species (Li et al., 2007; Ran et al., 2002b; Schaller et al., 1989), and identified six variables that may affect their occupancy probabilities (Table S1). We used a 30-m resolution DEM (ASTER, 2009) to delineate the elevation and slope raster. During camera deployment, field staff recorded the presence or absence of bamboo understory at each survey location, and identified the forest age (primary or secondary forest) and composition (broad-leafed, mixed, or coniferous forest). Geo-referenced data of human residences were obtained from the Shaanxi and Sichuan Forestry Departments. GIS layers were standardized to 100×100 m spatial resolution, and the mean value of elevation and slope, and the distance from each survey location to residences was calculated using ArcToolbox in ArcGIS 10.2 (ESRI, 2013).

We identified three variables that may affect the detection probabilities of our target species: monthly mean temperature, scent lure persistence, and camera trap model (Table S1). We obtained monthly mean temperatures from WorldClim Data (Hijmans et al., 2004), and categorized the temperature during each survey period into low (<5 °C), medium (5–15 °C), or high (>15 °C) accordingly (Winchell and Doherty, 2008). We divided the time since scent lure application during each survey into short (within 10 days), long (11–20 days), and none (>20 days or not applied) (Li et al., 2010a,b), and categorized the trigger delay of our camera models at each survey location into short ($\leqslant$1 s), or long (>1 s).

2.3. Data analysis

2.3.1. Occupancy modelling

We measured our survey effort by the number of 24 h periods (Tobler et al. (2008), and divided the camera-trapping duration at each survey location into 5-day segments (Li et al., 2010a). For each segment a species was considered "detected" if any detection was made during the 5 days, and "not-detected" otherwise. Prior to model construction, we examined the collinearity of variables