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Citizen science data facilitate monitoring of rare large carnivores in remote montane landscapes

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ABSTRACT

Population monitoring of large carnivores, particularly in remote montane landscapes, represents a considerable conservation challenge. Occupancy modeling using repeated detection/non-detection surveys offers a practical and robust tool for assessments of this type. Sign surveys or photographic detections have been the two primary survey methods to inform occupancy models. However, these approaches are expensive to implement and resource-intensive. Thus, their applicability for assessing the distribution of rare large carnivores residing in inaccessible landscapes is limited, particularly when large scale species monitoring is desired. Here, our intent was to predict the occupancy of the endangered Persian leopard (*Panthera pardus saxicolor*) inhabiting the rugged mountains of northeastern Iran. Using a Bayesian occupancy modeling framework, we compared patterns of leopard occupancy derived from standardized monitoring data implemented using spatially-replicated sign surveys to those informed by citizen scientist observations. We found that leopard occupancy probability was comparable between the two survey methods (sign survey = 0.92, 95% CI 0.85–1 and citizen science = 0.94, 95% CI 0.88–1) though detection probability varied (sign survey = 0.52, 95% CI 0.46–0.58 and citizen science = 0.25, 95% CI 0.18–0.32). The magnitude of effect among the environmental covariates that predicted leopard occupancy probability was also similar for the two methods. Thus, while yielding comparable predictions, the citizen science approaches were half the cost of sign surveys. The implementation of the effective citizen scientist data enabled us to expand by two-fold the monitored area while halving the costs in comparison to the area investigated via sign surveys. Our paper demonstrates that citizen science surveys represent a cost-effective, reliable, and surprisingly overlooked means to efficiently assess occupancy, particularly for rare large carnivores inhabiting mountainous landscapes.

1. Introduction

Mountainous ecosystems cover approximately 25% of global land surface area and support an estimated one-third of terrestrial biological diversity (Körner, 2004). These biodiversity hotspots also tend to have comparatively lower levels of human activity and anthropogenic disturbance (Tang et al., 2006; Myers et al., 2000). The conservation of large carnivores living in these landscapes represents a formidable challenge for conservationists and managers. For example, carnivores inhabiting mountainous landscapes tend to persist at lower densities than carnivores in lowland habitats (Bellemain et al., 2007; Alexander et al., 2015; Jiang et al., 2015). That rarity presents problems for accurate population estimation. Moreover, only one third of the current extant range of some large carnivores, such as big cats is projected to remain as suitable habitat in the next half century (Li et al., 2016; Ebrahimi et al., 2017), highlighting the vulnerability of large carnivores to demographic and environmental changes. Large carnivore rarity and vulnerability underscores the critical and time-sensitive need to develop efficient monitoring methods so that conservation plans have the greatest chance of success (Nichols and Williams, 2006; Nielsen et al., 2009).

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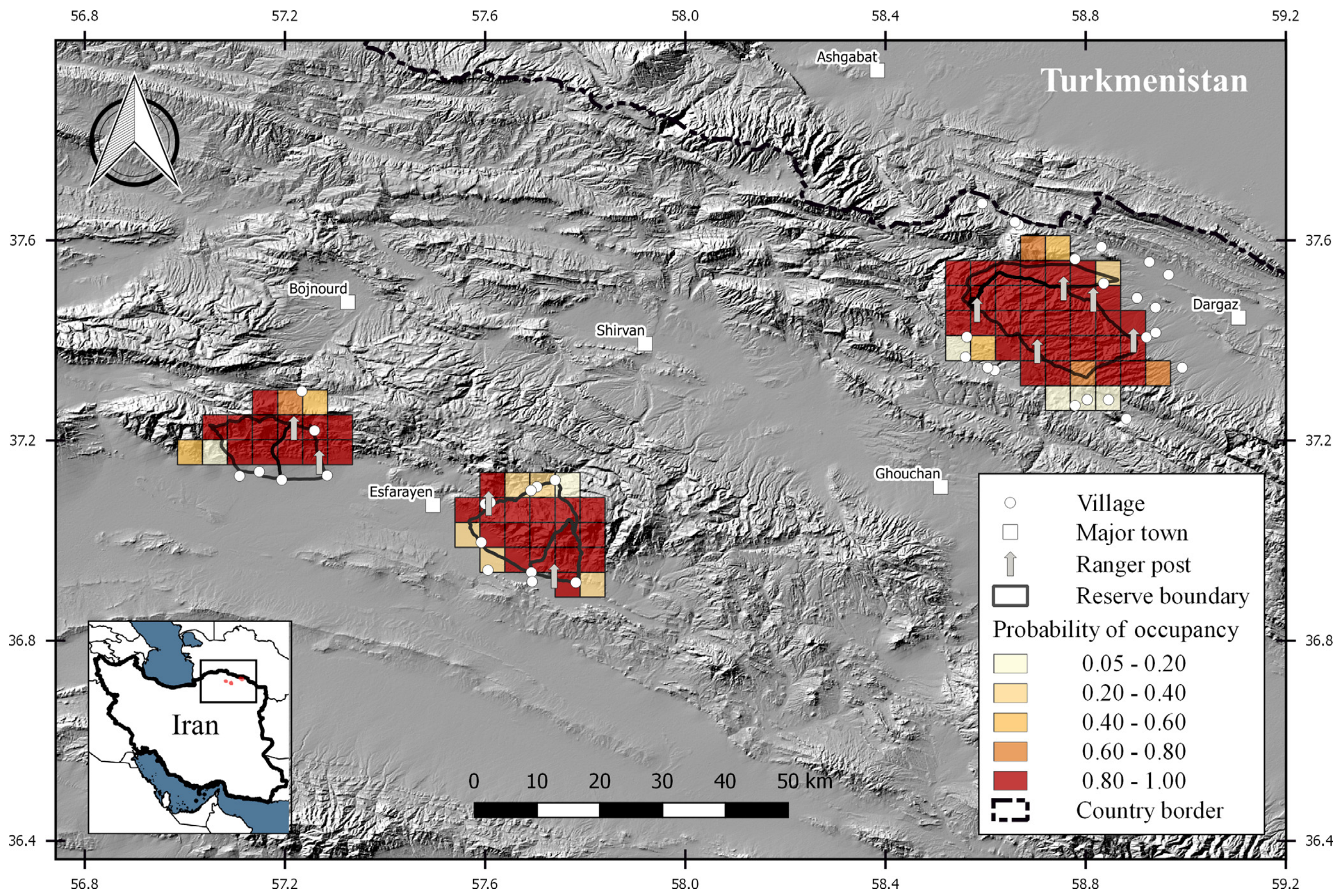

Fig. 1. The predicted relative probability of Persian leopard occupancy as calculated from models built using citizen science data in northeastern Iran. Each of 80 sites (cells) is depicted at a resolution of 25 km^2.

Conservation managers need reliable and cost-effective techniques for monitoring wildlife populations (Joseph et al., 2006). Occupancy modeling which accounts for imperfect detection, where a location is used by the species but is not detected, is a useful tool for monitoring rare and elusive species (MacKenzie et al., 2002; MacKenzie et al., 2006). This modeling framework develops predictions that can be interpreted as wildlife abundance or density (MacKenzie et al., 2006; Linden et al., 2017; Steenweg et al., 2018). In particular, temporal and spatial patterns in occupancy are often related to changes in animal abundance, and thereby provide insight into the probability of a species' occurrence (Noon et al., 2012). Occupancy modeling has been widely used for monitoring the population trends of rare large carnivores across time and space (Karanth et al., 2011; Henschel et al., 2016; Wibisono et al., 2011; Rich et al., 2017). Occupancy models can also be used to clarify habitat niche width of species on the generalist–specialist continuum (Moll et al., 2016), quantify species interactions (Steinmetz et al., 2013), evaluate large-scale species habitat-use (Petracca et al., 2018; Soofi et al., 2018), and improve the precision of abundance estimates in combination with capture–recapture methodologies (Blanc et al., 2014).

Sign and photographic detections surveys represent two common methods used to inform occupancy models for large carnivores (Khorozyan et al., 2010; Suryawanshi et al., 2013; Soofi et al., 2018; Alexander et al., 2016; Bischof et al., 2014; Steenweg et al., 2016). However, these techniques are both expensive and potentially time and resource intensive (Zeller et al., 2011; Miller et al., 2013; Soofi et al., 2018). These factors can diminish the applicability of these techniques, particularly in regions with poor funding, political instability, and difficult landscape accessibility. More recently, there has been a surge in interest in biogeographical studies based on data collected using 'citizen scientists' (Cooper et al., 2007). The application of citizen science approaches integrate public outreach and scientific data collection to supplement or substitute for other more expensive or intensive survey techniques (Dickinson et al., 2012; Strien et al., 2013). This field has been growing to include the monitoring of rare species (Zeller et al., 2011; Miller et al., 2013; Petracca et al., 2018; Shumba et al., 2018). Yet surprisingly, the potential application of citizen science approaches in quantifying the patterns of distribution and occupancy in large carnivores inhabiting mountainous regions has not been widely evaluated. If a citizen science approaches proved robust, it would provide an extremely cost-effective alternative to traditional methods used to study and monitor large carnivores in mountainous regions (e.g., using camera trap or sign surveys). Although previous work has shown that citizen science data can produce reliable estimates of distribution trends (Strien et al., 2013; Broman et al., 2014) and resource selection (Shumba et al., 2018), such data may also demonstrate a poor match with standardized monitoring data because of the lack of spatial and/or temporal non-randomness in sampling effort and decreased sensitivity to population changes (Kamp et al., 2016; Snäll et al., 2011). Therefore, citizen science data must be validated and their quality must be appropriately matched with research questions (Silvertown, 2009).

In this study, we critically evaluated the efficacy of using citizen scientist data in occupancy modeling of large carnivores inhabiting mountainous landscapes. We did so by deploying two data collection platforms to detect the endangered Persian leopard (*Panthera pardus saxicolor*) across multiple montane sites in northeastern Iran. First, we deployed the conventional standardized spatially-replicated sign surveys. Simultaneously, we conducted interviews with local villagers to access citizen scientist observations of leopard occurrence. We fitted occupancy models informed by both data collection formats using