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Spatial distribution drivers of Amur leopard density in northeast China

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ABSTRACT

The Amur leopard (*Panthera pardus orientalis*) is highly elusive, rare species, critically threatened with extinction worldwide. In this study, we conducted camera-trap surveys of an Amur leopard population in Jilin Province, northeast China. We estimated population abundance and density distribution, and explored the effects of prey population densities and biomass of prey, habitat and anthropogenic factors on the spatial distribution of Amur leopard density. Our results suggested that Amur leopard density was 0.62 individuals/100 km^2 and 16.58 individuals might live within the study area. The spatial distribution of Amur leopard density exhibited different responses to the population densities of different prey species. We found that two ecological thresholds existed in maximum responses of Amur leopard distribution to elevation and prey biomass. Vegetation and anthropogenic factors also showed significant effects on leopard population distribution. In general, there was a combination of habitat factors including, not only prey assembly and biomass, but also vegetation, anthropogenic and geographical factors driving the spatial distribution of Amur leopard population. These insights informed us that comprehensive adaptive landscape and prey conservation strategies should be conducted for saving this critically endangered predator.

1. Introduction

The Amur leopard (*Panthera pardus orientalis*) is an elusive subspecies of leopard, which currently occurs in northeast China and the Russian Far East. It is the most rare felid subspecies in the world and has been listed as critically endangered on the IUCN red list since 1996 (Jackson and Nowell, 2008). The Amur leopard is also a first class protected subspecies in China (Wang, 1998). There were an estimated 50 individuals in Russia according to the winter tracking survey of 2013 (http://www.tx2.org.cn/picvideo/ShowArticle.asp?ArticleID=831) and 41 individuals estimated in Russia by camera trap surveys from 2003 to 2011 (Aramilev et al., 2012). Yang et al. (1998) estimated less than 10 Amur leopards in China; however, this estimate for the size of the Amur leopard population is derived from a snow track survey, conducted in China primarily for Amur tigers (*Panthera tigris altaica*). During recent years, while searching for snow tracks of Amur leopards, a large part of the Amur leopard range in China was also surveyed. There were 8–11 Amur leopards found during one survey on the southern slopes of Laoye Mountain in Jilin, China, taken during the winter 2011 to spring 2012 (Wu et al., 2013). An additional 5–7 leopards have been identified on the southern slopes of Laoyeling Mountain in Heilongjiang, China, during a winter survey in 2013 (http://www.tx2.org.cn/News/ShowArticle.asp?ArticleID=894). However, the snow track method may not estimate the number of individual leopards accurately.

All wildlife requires food and space for life activities (Morris, 2003). Habitat loss is a leading cause of population decline and extinction of endangered or threatened species (Halley and Iwasa, 2011). Food shortage is also a limiting factor of top predator populations, particularly large carnivores (Ullas Karanth and Chellam, 2009). Therefore, abundance, and the spatial distribution of prey population, may influence habitat selection and spatial distribution of predators (Aryal et al., 2014). Animals select habitat under the concomitant influences of habitat quality, resource availability, interspecific competition and interspecific interaction (Fretwell and Calver, 1969; Rosenzweig, 1981; Morris, 1988). Abundance and the associated spatial distribution of prey or food resources also play a crucial role in determining when and where predators forage (Santora et al., 2011; Karanth et al., 2004). Consequently, carnivore density or abundance may be correlated with preferred prey densities and may, in turn, affect the relative abundance of prey (Trites, 2002; Karanth et al., 2004; Hayward et al., 2007). Studies concerning the effects of prey abundance and spatial distribution on the use of space by carnivores provide insights into more effective ways to ensure the conservation of large carnivores (Karanth et al., 2004). Leopards usually live in remote areas, which are difficult to access, but they also occasionally visit the outskirts of urban areas adjacent to their ranges (Khorozyan and Abramov, 2007). Amur leopards prefer Korean pine forests at low elevations, well away from main roads, and avoid deciduous forests, meadows, shrubs and agricultural fields

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(Hebblewhite et al., 2011). Little is known regarding the effects of both prey species and population abundance on the spatial distribution of the Amur leopard population in northeast China, in the regions bordering the Russian Far East.

Reliable spatial distribution estimates of population density are crucial to population conservation and habitat management of elusive endangered species (Sollmann et al., 2013; Li and Wang, 2013; Zimmermann et al., 2013; Zhang et al., 2014). Camera trapping is an effective, non-invasive technique for wildlife surveys and is currently a popular tool for estimating population sizes of elusive, rare species (Karanth, 1995). Individual identification technology based on distinctive fur patterns makes identification of individual large mammals possible and accurate with camera trap photograph data (Hiby et al., 2009). To our knowledge, no studies have estimated the population size of Amur leopards using statistical estimators based on camera trap data in China. Therefore, we used the camera trap method to survey Amur leopards starting in the spring of 2012 in the southern Laoye Mountain in Jilin. Subsequently, the first evidence of a wild Amur leopard with two kittens was obtained in October 2013 by camera traps (Jiang and Qi, 2014).

In this study, we first estimated the density and spatial distribution of Amur leopard populations using spatially explicit capture–recapture (SECR) models with camera trap data (Royle et al., 2009). Then we assessed relationships between leopard density distribution and prey abundance, total prey biomass, or other habitat factors. We hypothesized that: (1) the population abundance and spatial distribution of prey species influence the spatial distribution of the Amur leopard population; (2) anthropogenic disturbances would decrease the spatial distribution of Amur leopard density; and (3) vegetation and elevation are the main habitat factors determining the spatial distribution of Amur leopard density.

2. Methods

2.1. Study area

The study area is located in the southern slopes of the Laoye Mountain of Jilin Province, northeast China, and borders Russia (E 130.609°–131.309°, N 43.231°–43.559°; Fig. 1). The study area is an important part of Amur leopard habitat in China. It is a mountainous area, with elevations ranging from 200 m–1200 m. The climate is temperate continental monsoonal with annual average temperature of 1.5 °C. Total annual precipitation is 450–600 mm, and occurs mainly from May to September. The dominant vegetation at low elevations is secondary deciduous forest and mixed coniferous–deciduous forest is distributed at high elevations (usually 600–1200 m). Roe deer (*Capreolus pygargus*) and wild boar (*Sus scrofa*) are the dominant prey of Amur leopards. Other prey, such as red deer (*Cervus elaphus*) and sika deer (*Cervus nippon*), are found at low densities.

2.2. Field surveys

For this Amur leopard survey, we divided the study area into 84 units, with approximately 10 km^2 for each one. Camera traps were placed on leopard trails or at locations where mammal traces were found within each unit (Fig. 1). Two infrared cameras (LTL-5210A and LTL-6210, Shenzhen Weikexin Science & Technology Development Co., Ltd, Shenzhen, China) were set facing each another at each trap station to increase capture probabilities and capture the fur patterns on both sides of the leopard (Silver et al., 2004). Cameras were attached to trees 45–50 cm above the ground at a distance of 3.5–4 m from animal trails in order to take quality pictures of Amur leopards (Nichols and Karanth, 2002). Previous studies have found that female Amur leopard

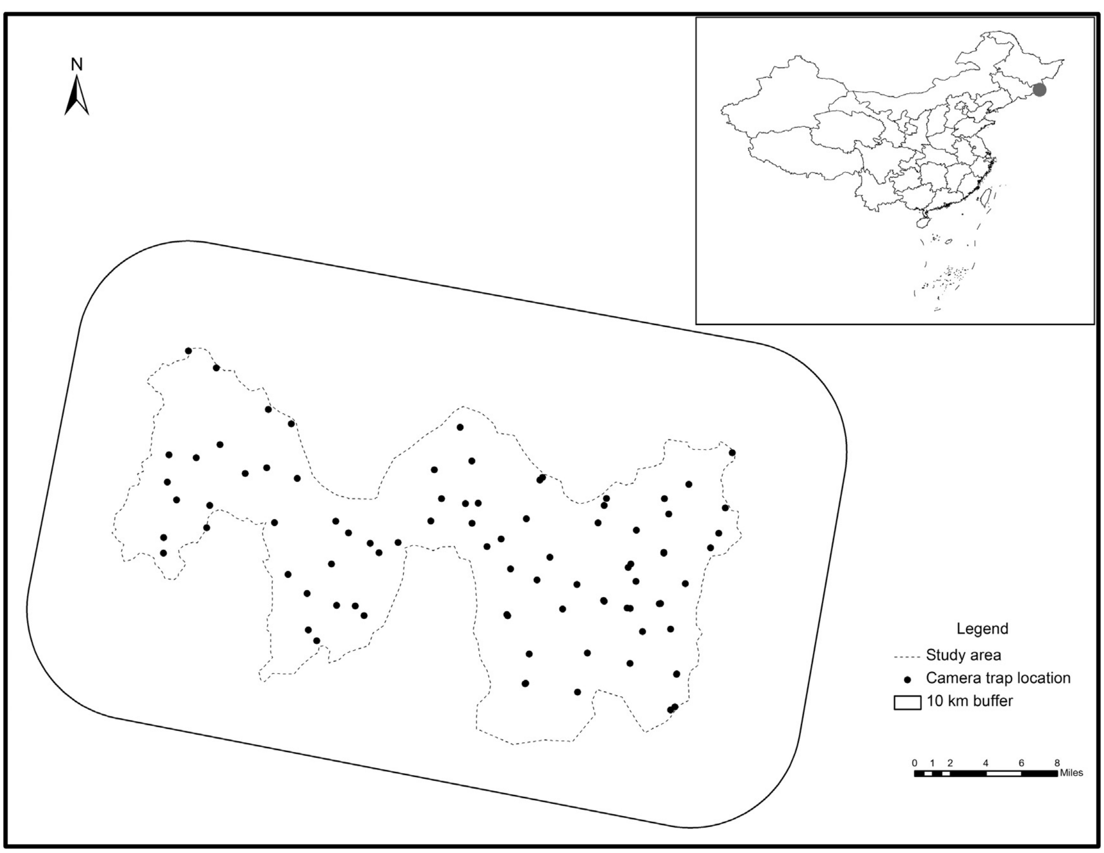

Fig. 1. Illustration of camera traps locations and survey area with a 10 km buffer zone. The study area is located in Jilin province, northeast China. The camera trap stations (black points) were in operation from April 2013 to July 2014.