



## Living on the edge: Opportunities for Amur tiger recovery in China

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### ABSTRACT

Sporadic sightings of the endangered Amur tiger *Panthera tigris altaica* along the China-Russia border during the late 1990s sparked efforts to expand this subspecies distribution and abundance by restoring potentially suitable habitats in the Changbai Mountains. To guide science-based recovery efforts and provide a baseline for future monitoring of this border population, empirical, quantitative information is needed on what resources and management practices promote or limit the occurrence of tigers in the region. We established a large-scale field camera-trapping network to estimate tiger density, survival and recruitment in the Hunchun Nature Reserve and the surrounding area using an open population spatially explicit capture-recapture model. We then fitted an occupancy model that accounted for detectability and spatial autocorrelation to assess the relative influence of habitat, major prey, disturbance and management on tiger habitat use patterns. Our results show that the ranges of most tigers about the border with Russia. Tiger densities ranged between 0.20 and 0.27 individuals/100 km<sup>2</sup> over the study area; in the Hunchun Nature Reserve, the tiger density was three times higher than that in the surrounding inland forested area. Tiger occupancy was strongly negatively related to heavy cattle grazing, human settlements and roads and was positively associated with sika deer abundance and vegetation cover. These findings can help to identify the drivers of tiger declines and dispersal limits and refine strategies for tiger conservation in the human-dominated transboundary landscape. Progressively alleviating the impacts of cattle and human disturbances on the forest, and simultaneously addressing the economic needs of local communities, should be key priority actions to increase tiger populations. The long-term goal is to expand tiger distribution by improving habitats for large ungulates.

### 1. Introduction

Asian forest ecosystems are becoming increasingly fragmented by the extensive intensification of anthropogenic activities (Joshi et al., 2016; Z.W. Li et al., 2009; Wang et al., 2012). As a result, tigers (*Panthera tigris*) have declined steadily since the end of WWII and are on the brink of local extinction in many areas (Gopal et al., 2010; Walston et al., 2010). Tigers, a flagship species and the apex predator in Asia, exemplify the problems faced by most large carnivores worldwide; they have experienced substantial population declines and range contractions during the past century (Dinerstein et al., 2007). Despite decades of conservation actions, human land use has led to a steady loss of habitat and as a result, once large and continuous populations have

mostly been subdivided into smaller, less viable populations (Carroll and Miquelle, 2006; Kenney et al., 2014; Rayan and Linkie, 2015; Walston et al., 2010). To better understand the consequences of habitat fragmentation and degradation, recent conservation research has focused on how tigers use and disperse through human-dominated landscapes (Carter et al., 2012; Chanchani et al., 2016).

Attempts at recovering small, threatened populations of Asian carnivores often involve expanding their range beyond extant protected areas and international borders (Carter et al., 2012; Chanchani et al., 2016; Linnell et al., 2016; Smith et al., 1998). In Northeast China recovery of tigers will require expanding conservation efforts beyond the border with Russia into landscapes where human activities and biodiversity conservation must be integrated. This is the case with the

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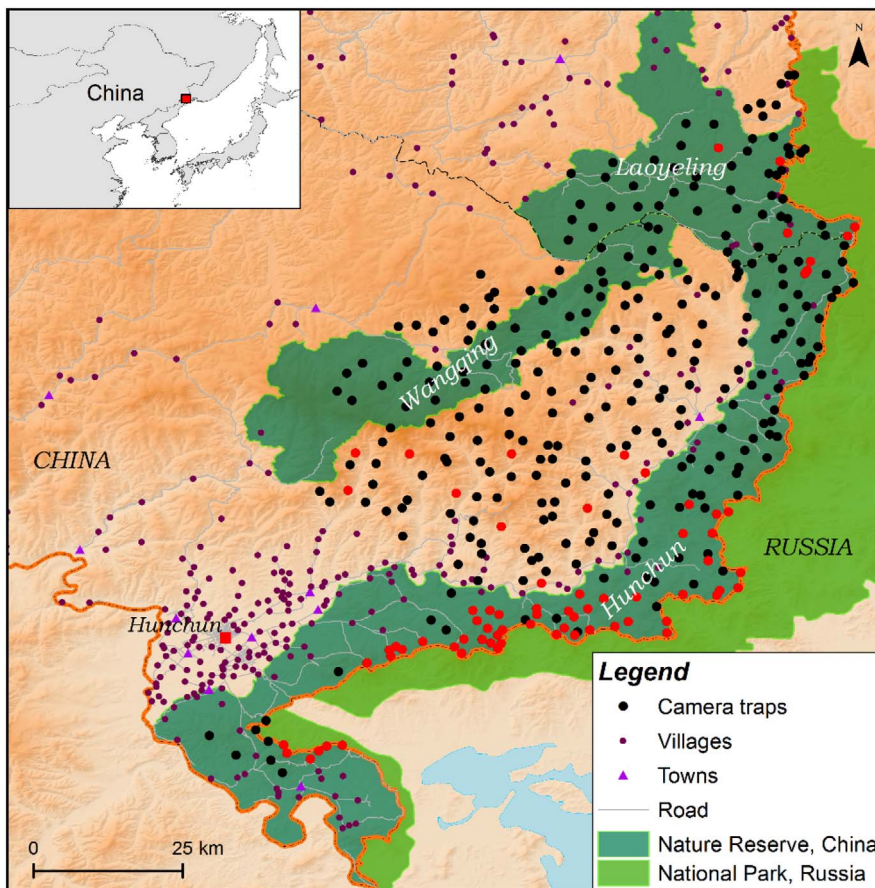


Fig. 1. Monitoring areas of the long-term Tiger-Leopard Observation Network (TLON) in NE China showing camera placement relative to settlements, major roads and nature reserves or national parks. Red dots represent the sample locations (camera traps) where tigers were observed. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

endangered Amur (Siberian) tiger (*P. t. altaica*), which occurs on the northern fringe of the tiger's range. This subspecies plays a vital role in structuring the mixed coniferous and broad-leaved forest ecosystems of Northeast Asia (Luo et al., 2004; Miquelle et al., 2010b). Historically, tigers were once distributed widely across much of Northeast China, the Far East of Russia and the Korean Peninsula, but in recent decades they have experienced severe demographic and geographic range contractions due to habitat loss, poaching, prey depletion and disease (Gilbert et al., 2015; Miquelle et al., 2010a; Tian et al., 2011; Wang et al., 2016). Currently < 600 individuals are estimated to remain in two isolated subpopulations confined to the Sikhote-Alin Mountains of Russia (95% of individuals) and the Changbai Mountains along the China-Russia border (5%) (Miquelle et al., 2006; Tian et al., 2009). Movement between the two subpopulations is blocked by an urbanized rail and highway corridor and wetlands (Carroll and Miquelle, 2006; Hebblewhite et al., 2014; Miquelle et al., 2015), resulting in genetic divergence (Henry et al., 2009; Sorokin et al., 2016). This subspecies has the lowest genetic variation of all extant tiger subspecies and the Southwest Primorye/Changbai Mountains population has an estimated effective population size of 11–14 (Alasaad et al., 2011; Dou et al., 2016; Henry et al., 2009). The future of the Amur tiger, especially this smaller, isolated transboundary population is at a crucial threshold. Adequate conservation efforts are needed in Northeast China to restore landscape permeability so that tigers can once again occupy what is now a mixture of natural and human dominated habitat (Pitman et al., 2017; Yumnam et al., 2014).

Since the late 1990s, this border population has gradually increased and is extending its distribution into China (T.M. Wang et al., 2015; Wang et al., 2016; Wang et al., 2014). This transboundary population shares land with the only remaining population of the Amur leopard (*Panthera pardus orientalis*). These carnivores currently compete with local people for limited resources (e.g., food) as agricultural expansion,

infrastructure development, and forest logging have seriously jeopardized their viability (Tian et al., 2011; Wang et al., 2016). In particular, changes in land-use policies in the Changbai Mountains have led to an increase in cattle ranching over the past 20 years, which has resulted in habitat degradation and the exacerbation of human-tiger conflicts (Soh et al., 2014; Wang et al., 2016). Thus, a conservation strategy is urgently needed that provides ecological services for human needs and habitat for tigers and leopards.

Despite recent research that has increased the understanding of Amur tiger ecological requirements (e.g., habitat connectivity, prey availability and human disturbance) (Carroll and Miquelle, 2006; Hebblewhite et al., 2014; Miquelle et al., 2010b; Petrunenko et al., 2016), significant knowledge gaps remain. In particular, programs that prioritize the initiation of such recoveries should be evidence-based, requiring assessments of landscape-wide conditions for this population, which are typically unclear in China. To improve the conservation outlook for the tiger, in 2016 the Chinese government initiated a Tiger-Leopard National Park (TLNP) program to expand the Amur tiger and leopard ranges in China (McLaughlin, 2016). The TLNP is connected to the Land of Leopard National Park (LLNP) in southwest Primorye Krai, Russia, but on the Russian side of the border, habitat is limited. In contrast, in China, there is extensive potential habitat, but wildlife face pressure from rapid land-use changes and high levels of anthropogenic activities. In particular, peripheral anthropogenic encroachment and activities have largely confined tigers to the reserve (Wang et al., 2016). Hence, understanding how tiger abundance and habitat use in China vary in response to environmental and anthropogenic factors and existing land management practices (i.e. livestock grazing) is essential for re-establishing tigers in China. There is also a clear need to identify how protection designation (inside and outside protected area) influence tiger occurrence at local and landscape scale, to inform land-use planning and wildlife management.

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