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Effects of human disturbance on vegetation, prey and Amur tigers in Hunchun Nature Reserve, China

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ABSTRACT

Multiple human disturbances influence the vegetation, ungulates and Amur tigers (*Panthera tigris altaica*) in Hunchun Nature Reserve (HNR) in northeastern China. In order to understand the influence and relative contribution of human disturbance on Amur tigers, prey and vegetation, we conducted the transect lines and plot surveys of human disturbance inside HNR from August to October 2013. We used generalized additive models, generalized liner models and structural equation models to explore the effects of human disturbance on vegetation, prey and Amur tigers. We then used hierarchical partitioning models to quantify the contribution of four main kinds of human disturbance. Our results suggest that all three models indicate that human disturbance can directly and indirectly affect prey and Amur tigers via the Bottom Up chains. Among the human disturbances, grazing activity and ginseng land encroachment impacted vegetation more than roads did; for prey, secondary roads had the greatest impact. Grazing activity, secondary roads and primary roads were the main factors disturbing Amur tigers. The generalized additive model had a stronger detection ability for disturbance prediction than generalized liner and structural equation models. The generalized additive model detected more complex nonlinear interaction relationships between predator and prey or predator, prey and habitat factors. Reducing or eliminating specific types of disturbance will be essential to recover Amur tiger populations and their habitats.

1. Introduction

The effects of human disturbance on vegetation and wildlife in human-dominated landscapes is a critical issue in wildlife management. In recent decades, conflict between people and wildlife has become more frequent because of the exponential increase in the human population and spread of human activity (Woodroffe, 2000; Conover, 2002; Pettigrew et al., 2012). The human disturbance results in habitat loss, either directly or indirectly as a consequence of avoidance behavior by affected wildlife (Mace and Waller, 1996), and may cause wildlife to shift the habitat use and reduce the forage quality (Hernandez and Laundre, 2005). Large carnivores (>40 kg) are more susceptible to human disturbance and changes in the configuration and connectivity of habitats such as habitat fragmentation and loss (Dusit et al., 2007). Some identified human disturbances effecting tigers (*Panthera tigris Linnaeus*, 1758) include roads, settlements, farmlands, logging, poaching, grazing and quarrying (Bishnu and Pavel, 2013; Kerley et al., 2002; Barber-Meyer et al., 2013). Some studies have suggested that the prey abundance and the human disturbance are the most important parameters for tiger occupancy, and serious disturbances can cause prey depletion and tiger extinction (Bishnu and Pavel, 2013). However, most research about the human disturbances is descriptive, only explores a few causes of disturbance, and rarely yields mechanisms. The majority of wild tigers remain affected by human disturbance, even in conservation zones (Linkie et al., 2003). Further, little research has compared the contribution of different disturbances affecting wildlife and vegetation. In nature, different factors often have different contributions to the survival of taxa (Tisseuil et al., 2013) and many disturbance factors have interactions that affect taxa (Soh et al., 2014). Therefore, just focusing on particular disturbances may cause one-sided problems,

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and comparing different types of human disturbances allows an understanding of the deep and complex mechanisms threatening wildlife.

As one of the few areas where the wild Amur tiger (*Panthera tiger*) and leopard (*Panthera pardus*) coexisting in China, Hunchun Nature Reserve (HNR) is a key area for Amur tiger (*Panthera tigris altaica*) and leopard conservat-ion. Because of the habitat loss and intensified human disturbance, Amur tiger was at the brink extinction in the late 1990s in northeast China (Miquelle et al., 2010). The Chinese government has taken some measures to reverse the trends, especially in "The Natural Forests Protection Program" initiated in 1998, which have led to substantial improvements in the quantity and quality of forests in Northeast China (Wei et al., 2014). Until the year of 2015, at least 26 Amur tigers was found within China, which are confined primarily to a narrow area along the border with Russia just like HNR (Wang et al., 2016). Now the Chinese government is preparing a national park for Amur tiger and leopard in Jilin and Heilongjiang provinces in the northeast during which HNR plays as critical role for the big feline conservation (http://www.chinadailyasia.com/nation/2016-05/18/content_15434991.html). Even though, there are still vario-us human disturbances in HNR. We hope our researches could find the mecha-nism of the human disturbances on vegetation, prey and Amur tigers, and qua-ntify them at the same time, to support the basic references for the goverment, policy makers and conservationists.

The main human disturbances around HNR include roads, grazing, ungulate poaching (snares) and crop cultivation (ginseng and other farmland). A few studies have involved the human disturbances in HNR and tiger abundance, leopards and ungulates (Li, 2009; Li et al., 2006; Chen et al., 2011). Due to historical problems, many pastures remain in HNR and grazing is a typical human disturbance across the Hunchun region. The research on grazing has mainly focused on habitat selection of livestock depredation (Liu et al., 2005; Li et al., 2009) and not assessed the real effect of disturbance on Amur tigers and their habitat. Soh et al. (2014) showed that the probability of livestock depredation by Amur tigers increased in areas close to ungulate snares and there was an overall lower density of ungulate prey closer to snare sites. The ginseng cultivation is another typical disturbance in Hunchun and requires the cleaning of all trees and shrubs and establishment of blue greenhouses that result in large habitat loss. Ginseng planting also requires chemical fertilizer and pesticides which may affect vegetation. Roads are a kind of serious disturbance for wildlife and tigers in HNR (Smirnov and Miquelle, 1999). In the Russian far east, roads decrease survivorship and reproductive success of Amur tigers (Kerley et al., 2002). Although logging was ceased since the HNR establishment, many logging roads are still used and remolded for national defense near the border, the collection of non-timber forest products and the tourism. There are three kinds of roads within or around HNR: tertiary, secondary and primary roads (Fig. 1). Most tertiary roads are abandoned logging roads used by local people, possessing rugged condition and gravel-paved only for the farm vehicle; secondary roads are used for connecting villages around HNR with cement paved all year-round; and primary roads with asphalt paved are not inside the HNR, connecting Jilin and Heilongjiang Province and allowing the traffic to move at high speed.

The purpose of the statistical model is to provide a mathematical basis interpretation, exame such parameters as fit (do the measured predictors adequately explain the response?), strength association (is the relationship between the response and the predictors significant?), and ascertain the contributions and roles of different variables (Guisan et al., 2002). Different kinds of models provide different insights into the role of statistical modeling in ecology (Guisan et al., 2002) and aim to provide insights into the ecological processes that produce patterns (e.g. Austin et al., 1990). As the mathematical extensions of linear modeling (LM), generalized liner models (GLMs) do not force data into unnatural scales, and thereby allow for non-linearity and non-constant variance structures in data (Hastie and Tibshiran, 1990). Data assumed to be from several families of probability distributions, including the normal, binomial, Poisson, negative binomial, or gamma distribution, many of which better fit the non-normal error structures of most ecological data (Guisan et al., 2002). GLMs are more flexible and better suited for analyzing ecological relationships, which can be poorly represented by classical Gaussian distributions (Austin, 1987). Generalized additive models (GAMs) (Hastie and Tibshirani, 1986, 1990) are semi-parametric extensions of GLMs; the only underlying assumption made is that the functions are additive and that the components are smooth. The strength of GAMs is their ability to deal with highly nonlinear and non-monotonic relationships between the response and the set of explanatory variables for which the GLMs do not have strong capacity to handle (Guisan et al., 2002). GAMs represent the real responses of species to the environment for data characteristics and nonlinear functions (Suarez-Seoane et al., 2002). One advantage of structural equation models (SEMs) is to estimate and test relationships among constructs while GAMs and GLMs only reveal correlations between the response and explanatory variables alternately. Compared with other general linear models, SEM, which estimate causal effects through the study of path relations (Grace et al., 2010), allows for the use of multiple measures to represent constructs and addresses the issue of measure-specific error (Weston and Gore, 2006).

Top-down and bottom-up effects are classic mechanisms known to affect prey and predator systems (Sabatier, 1986; Hunter and Price, 1992; Suarez and Case, 2002; Aryal et al., 2014). Bottom-up effects combined with the climate change, virology and fear ecology can better reveal interactions between prey and predators (Wilmers et al., 2006; Laundre et al., 2014) which form the focus of the present study. Specifically, understanding the relative importance of bottom-up effects is critical for predicting impacts on top predators (Frederiksen et al., 2006). Predicted patterns and correlations between predators and prey under various control mechanisms differ markedly: positive correlations suggest strong bottom-up control, negative correlations indicate strong top-down control and weak or no correlations between predators and prey suggest weak trophic links or insufficient data (Worm and Myers, 2003).

Here, we aimed to identify the real threats to Amur tigers and provide recommendations for eliminating or mitigating the effects of human disturbance. We hypothesized that (1) the human disturbance influences vegetation, prey and Amur tigers via bottom-up effects in HNR, and (2) different disturbances have different effect intensities on specific biological hierarchies along bottom-up chains. Because the variables of human disturbance, vegetation, prey and Amur tigers are from several families of probability distributions and the ecology relationship among them may be nonlinear or non-monotonic, we will combine the GAM and GLM to build the models. And to test the top-down and bottom-up effects, the SEM will be used to estimate relationships among the variable constructs and quantify the effect contribution of the human disturbance.

2. Methods and techniques

2.1. Study area

Hunchun municipality is a 4938 km^2 area in Jilin province, northeast China. The actual reserve, HNR, covers 1087 km^2. HNR borders Russia to the east and North Korea to the south west and includes four management zones (core area, experimental area,