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# An integrated analysis into the causes of ungulate mortality in the Wanda Mountains (Heilongjiang Province, China) and an evaluation of habitat quality

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ABSTRACT

As part of our ungulate population protection program, the specific causes of ungulate mortality were examined and the effect of single habitat on habitat selection by ungulate analyzed. An integrated occurrence–mortality model for three ungulate species (wild boar *Sus scrofa* L., red deer *Cervus elaphus* L. and roe deer *Capreolus capreolus* Pallas) within the Wanda Mountains of Heilongjiang Province, China was then created. Results showed that steel cable snares and poison, used to kill ungulates, were the primary threats to survival of wild boar (40.07% poison, 27.79% cable snares), red deer (51.35% poison, 40.54% cable snares) and roe deer (29.31% poison, 56.90% cable snares). Furthermore, we found evidence that aspect, slope, elevation and forest type are important factors in determining ungulate habitat preference. The integrated occurrence–mortality model indicated that 46.39% of suitable habitat was associated with mortality risk. This model correctly classified 8.06% (297.49 $km^2$) of the study area as unsuitable habitat, 5.43% (200.44 $km^2$) as first attractive sink-like habitat, 32.76% (1209.85 $km^2$) as second attractive sink-like habitat, 8.20% (302.77 $km^2$) as third attractive sink-like habitat, and 8.91% (329.00 $km^2$), 30.53% (1127.22 $km^2$) and 6.11% (225.29 $km^2$) as first, second and third source-like habitats, respectively. The results indicate that source-like habitats should be preserved to prevent habitat loss and degradation, while attractive sink-like habitats should be managed effectively to mitigate mortality risks. In particular, the various authorities need to be more proactive (increase patrolling, thereby providing employment, educational opportunities and increasing income) to reduce human-caused ungulate mortality.



## 1. Introduction

In many parts of the world, large wild ungulates are a significant economic resource for local and regional communities (Corlett, 2007; Loibooki et al., 2002; Bushmeat, 2010); however, illegal hunting for wild bushmeat is a real threat to their survival (IUCN, 2010). Numerous reports have shown that poaching has reduced some ungulate populations to crisis levels (Milner-Gulland and Bennett, 2003; Baillie et al., 2004; Corlett, 2007; Sodhi et al., 2004). This crisis is particularly noticeable in the Wanda Mountains of Heilongjiang Province, China. Increasing development pressure on natural resources in the Wanda Mountains has presented local researchers and management authorities with a unique dilemma: on the one hand, road construction and logging has boosted economic development, on the other, it has also provided easier access for poachers (Blake et al., 2007). In an effort to find the most effective measures for preserving large ungulates (Zhang and Liu, 2008), conservationist studies have focused on habitat selection and spatial distribution (Jiang et al., 2006; Zhang et al., 2007). Habitat selection models by ungulate species have been developed, providing an effective conservation plan. However, the analyses, as with many habitat suitability models, are limited due to lack of data on human-caused ungulate mortality, leading to erroneous conclusions if species occurrence does not correspond with positive reproductive and survival rates (Garshelis, 2000).

Some conservationists believe that high quality habitats, identified within habitat models and generated by species occurrence alone, might actually be located in ecological sink areas where reproductive and/or survival rates are too low and the mortality risk is too high to sustain a viable population. The attractive sink as a high quality habitat is a particular case where animals perceive an area as a good habitat, even though human-caused habitat modification will ultimately reduce demographic performance (Delibes et al., 2001; Naves et al., 2003). The identification of attractive sinks as high quality habitat will lead to erroneous conclusion in management and conservation plans. Naves et al. (2003) originally proposed the identification of attractive sink-like habitats using a two-dimensional habitat model, while Nielsen et al. (2008) considered both variables in occurrence and human-caused mortality models. Following this approach, Alessandra et al. (2009), using ecological niche factor analysis, evaluated habitat quality for

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conservation via an occurrence–mortality model. They built a two-dimensional model, i.e. an occurrence and human-caused mortality model, and then integrated the reclassified models. Alessandra et al. (2009) defined seven habitat states based on the interactions between suitability and mortality risk categories: unsuitable habitats (unsuitable class in the occurrence model and all mortality risk values), attractive sink-like habitats (medium and high mortality), and source-like or secure habitats (no and low mortality risk). Although the integrated occurrence–mortality model performed better for habitat analysis, considering demographic features, it failed to resolve how species respond to a single habitat factor, analyzing human-caused mortality only in the process of habitat selection for occurrence and survival.

Knowledge of mortality rates and causes of mortality are important in understanding ungulate population dynamics. Datasets on mortality and survival have yielded a real opportunity to analyze the causes of mortality and insights into ways of conserving current populations by reducing mortality (Groom, 2006). The habitat selection index (*HSI*), for example, is an effective way of analyzing the effects of specific factors on animal habitat selection (Johnson, 1980; Manly et al., 2002). The *HSI* is usually produced using species presence to infer the preference of a consumer for a particular habitat component (Jiang, 2006). Habitat suitability index models, based on *HSI*, are usually generated to infer habitat quality (Duberstein et al., 2008; Guisan and Thuiller, 2005). The integrated occurrence–mortality model is based on both the occurrence and mortality models, and can be used to develop suitable strategies for conservation and management (Alessandra et al., 2009).

In analyzing habitat selection and quality evaluation using the two datasets on occurrence and human-caused mortality, our goals were: (a) to analyze the causes of mortality in wild boar, red deer and roe deer, (b) to analyze habitat factors affecting ungulate occurrence and mortality, (c) to generate an integrated occurrence–mortality model which can be used to distinguish between attractive sink-like and source-like habitats, and provide effective management strategies.

## 2. Study area and background

Our study area covered 3 692.06 km$^2$, located between 132°48′52″ and 133°56′55″E and 46°07′55″ and 47°01′41″N, where the population of wild boar, roe deer and red deer have been recorded over the last 37 years (Ma, 1986). The study area bordered the Russia Far East and was dominated by mountains with mean elevations of ~200 m. Vegetation types included coniferous deciduous forest, coniferous/broad leaved mixed forest, broad-leaved forest, shrub land, forest wetland, and farmland. Mean annual rainfall ranges 500–800 mm. Temperatures, however, vary considerably throughout the year, with a monthly maximum temperature of 34.6 °C and monthly minimum temperature of −34.8 °C. Snow begins to fall in late November, to a maximum depth of 110 cm, and does not begin to thaw until the end of April. Human density (higher at lower elevations) is 32 inhabitants km$^{-2}$ at township level.

The diversity of habitat reflects the biodiversity, supporting animals such as wild boar, red deer, roe deer, goral (*Naemorhedus goral*), snow hare (*Lepus timidus*), and amur tiger (*Panthera tigris altaica*) (Li et al., 2008). However, forest clearance and human subsistence poaching has reduced the population number of wild boar, red deer and roe deer (Zhou et al., 2010). The Chinese government has passed several laws and regulations in the fight against poaching, and civilian-held guns were confiscated by the Government in the mid-1990s. Population recovery of these three ungulate species is an urgent issue for wildlife conservation authorities in the study area.

## 3. Materials and methods

### 3.1. Mortality data

We obtained two datasets on ungulate mortality in the Wanda Mountains. The first dataset included indirect or direct signs of ungulate occurence from line-transect surveys of ungulate population abundance in later winter 2008 to early spring 2009. The second included indirect or direct signs obtained from a long-term monitoring program of the amur tiger population between 2002 and 2009 (Zhou et al., 2008). A total of 160 cases (58 wild boar, 40 red deer and 62 roe deer) was collected. We edited the datasets for spatial accuracies and spatial–temporal independence, with selection locations of at least 500 m and 24 h apart. From these, we excluded nine cases with inaccuracies or missing coordinates to account for anthropogenic ungulate mortality. We therefore used 151 human-caused mortality cases (56 wild boar, 37 red deer and 58 roe deer) for analysis. Two datasets were pooled and the inputs used for the mortality model of the three ungulate species.

### 3.2. Cause of mortality in the three ungulate species

We combined the mortality datasets from the line-transect surveys of ungulate population abundance and long-term monitoring of the amur tiger population. The causes of ungulate mortality were examined and the principle causes grouped into four categories: (1) natural mortality, (2) human-caused mortality by cable snares, (3) human-caused mortality by poison, (4) human-caused mortality by hunting with hounds. The year was split into two periods from November to April (snowfall period), and May to October (non-snowfall period).

### 3.3. Survey design and data collection

Ungulates were difficult to observe directly due to low population density and high sensitivity to human disturbance. The information on ungulate occurrence and locations is based on snow–tracks surveys. Datasets were collected over two time-periods. The first dataset included GPS locations of ungulate activity collected along 105 line transects (each line transect was 5 km in length) in later winter 2003, 2004 and 2006, as well as in earlier spring 2005 (135 activity locations for wild boar, 165 for red deer and 258 for roe deer). The second dataset included 234 activity locations collected along 240 line transects in later winter 2008, and early spring and later winter 2009 (63 activity locations for wild boar, 54 for red deer and 117 for roe deer). A total of 240 line transects, 5 km in length, were place in forest stand maps with the beginning and end locations demarcated. Line transects were randomly assigned to a sub-sample of these predetermined locations, which were accessible to the surveyors. Surveyors walked slowly (<0.8 km h$^{-1}$) along the line transect noting animal signs (tracks, dung, fecal material, evidence of foraging), recording habitat factors and collecting mortality events. Participants either worked for ungulate conservation organizations for many years or had experience in the forestry areas, and were specially trained in field survey techniques.

### 3.4. Analysis of habitat selection

#### 3.4.1. Habitat selection index based on occurrence locations: ungulate occurrence model

In this study "habitat type" represents a category within a "habitat class", which in turn signifies a geographical or biological