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# Mapping seasonal European bison habitat in the Caucasus Mountains to identify potential reintroduction sites

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ABSTRACT

In an increasingly human-dominated world, conservation requires the mitigation of conflicts between large mammals and people. Conflicts are particularly problematic when resources are limited, such as at wintering sites. Such conflicts have fragmented many large mammal populations, making reintroductions in suitable sites necessary. Broad-scale habitat suitability mapping can help to identify sites for species' reintroductions. The European bison is a good example of a large mammal that is restricted to only a fraction of its former range. The goal of our study was to identify and assess potential habitat for European bison in the Caucasus Mountains, which is a part of its former range and has the potential to harbor larger populations. Specifically, we used seasonal presence data from four reintroduced European bison populations and two sets of predictor variables to: (i) map habitat suitability for summer and winter, (ii) characterize habitat based on management-relevant categories that capture the potential for conflicts with people, and (iii) identify candidate sites for reintroductions. We found substantial areas of suitable habitat. However, areas of potential conflicts with people were widespread and often near highly suitable areas. We identified 69 potential reintroduction sites (10 230 km$^2$, 1.8% of the ecoregion) that have suitable summer and winter habitat with relatively low risk of human–wildlife conflict. These results can guide conservation efforts in establishing a viable European bison metapopulation in the Caucasus ecoregion. More broadly, our results highlight the need to map large mammal habitat suitability for different seasons in order to derive meaningful conservation recommendations.



## 1. Introduction

Large mammals are threatened in many parts of the world, mainly because of habitat loss, over-hunting, and conflicts with people and their land use (Cardillo et al., 2005; Hoffmann et al., 2011; Ripple et al., 2015). Many large mammal populations are therefore small and isolated, making them prone to extirpation (Di Marco et al., 2014). This is worrisome, because large mammals play key roles in ecosystem functioning (Jaroszewicz et al., 2013; Pringle et al., 2007), often serve as umbrella species (Branton and Richardson, 2011), and are iconic flagships for conservation. Identifying ways to protect large mammal species in increasingly human-dominated landscapes is thus a key priority for conservation science (Hoffmann et al., 2011; Ripple et al., 2015).

Conservation planning for large mammals requires mapping suitable habitat for protecting and enlarging existing populations, for identifying corridors between them, and for locating candidate sites for future reintroductions (Hebblewhite et al., 2011; Schadt et al., 2002). Species distribution modeling is an important tool to understand habitat selection and predict habitat patterns (Elith and Leathwick, 2009; Engler et al., 2004; Guisan and Thuiller, 2005). In human-dominated landscapes, habitat models must include measures of potential conflicts with people (e.g., Hebblewhite et al., 2014; Kuemmerle et al., 2014; Zhou and Zhang, 2011), and if spatially explicit data on underlying threats, such as poaching, is lacking, then proxy variables, such as distance to roads or settlements, are typically used. However, when proxy variables for conflict are immediately combined with resource-related variables in habitat models, then it becomes more difficult to assess what ultimately drives habitat suitability. Moreover, habitat models that include conflict variables are ill-suited to identify areas that may act as population sinks because they offer attractive

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but risky habitat (i.e., ecological traps, Delibes et al., 2001; Naves et al., 2003). That makes it advantageous to parameterize models characterizing environmental and human conflicts separately (Naves et al., 2003), but such a two-step modeling approach has only been applied a few times, and mainly for large carnivores (e.g., De Angelo et al., 2013; Kanagaraj et al., 2011; Martin et al., 2012).

Another important issue when modeling habitat of large mammals arises from the fact that their habitat needs can vary considerably among seasons. However, most modeling applications so far have modeled large mammal habitat for a single season, usually summer. This is problematic for two reasons. First, summer habitat is typically more widespread than winter habitat, especially for large ungulates, but survival rates are typically lower in winter (Mysterud et al., 2007). Second, summer and winter habitat may differ in location and spatial pattern, meaning the protection of the species' full annual range is necessary to ensure its survival and thus to achieve conservation goals (Gavashelishvili, 2009; Kuemmerle et al., 2014; Martin et al., 2007).

European bison (*Bison bonasus*), Europe's largest terrestrial mammal, is a great example of a species restricted to a few small and isolated populations (Kuemmerle et al., 2012; Pucek et al., 2004). European bison went extinct in the wild in the early 20th century and the last free-ranging individual was poached in 1927 in the western Caucasus (Krasińska and Krasiński, 2007). A small number of European bison survived in zoos though, and a reintroduction program began after World War II. Today, about 3220 animals live in 40 wild, but small and isolated populations (Raczyński, 2013). The Caucasus is one of the species' strongholds, with three herds harboring together more than 500 bison (Sipko et al., 2010). Yet, the effective population size ($N_e$) of European bison in the region is too small to be viable (i.e., $N_e > 400$–500 individuals, Olech and Perzanowski, 2002; Pucek et al., 2004; Tokarska et al., 2011) and there is no natural exchange among the herds, which is especially problematic because of the genetic bottleneck that the species went through (only 12 captive founders). Furthermore, a suite of human threats have caused population declines for bison and other wildlife after the collapse of the Soviet Union (Bragina et al., 2015a; Di Marco et al., 2014; Krasińska and Krasiński, 2007). Poaching was the main reason and may continue in some parts of the Caucasus (Sipko, 2009; Trepet and Eskina, 2012). Other threats include illegal logging, pollution, armed conflicts, and infrastructural development (Cheterian, 2008; Zazanashvili and Mallon, 2009).

The Caucasus contains some of the last remaining wilderness areas in Europe where apex predators and large ungulates still exist in large enough numbers to shape ecosystem processes (Estes et al., 2011; Zazanashvili and Mallon, 2009), making it a prime candidate site for further bison reintroductions (Sipko et al., 2010). Indeed, a trans-national conservation plan for the Caucasus lists European bison as one of 26 priority species with the target to achieve a healthy and safe population by 2025 (Williams et al., 2006; Zazanashvili et al., 2012). Identifying suitable habitat, especially winter habitat, with low risk for human–wildlife conflict is critical to reach this target. However, prior studies focused either on very small study sites (Klich and Perzanowski, 2012; Nemtsev et al., 2003) or covered the Caucasus in a coarse-scale habitat suitability analysis as part of the species' former range (Kuemmerle et al., 2011). A detailed habitat analysis for different seasons and for the entire region is still lacking.

Our first objective was to map potential European bison habitat in both winter and summer for the Caucasus region. Our second objective was to distinguish suitable habitat that is safe, from suitable habitat with high potential for human–bison conflicts (i.e., ecological traps), and safe but only marginally suited habitat (i.e., potential refuges). Finally, our third objective was to identify patches with sufficient winter and summer habitat and low human impact as candidate sites for potential future reintroductions.

## 2. Data and methods

### 2.1. Study area

The Caucasus harbors high levels of biodiversity, including many endemics (Mittermeier et al., 2004; Myers et al., 2000; Zazanashvili et al., 2012). The ecoregion is located between the Black and Caspian Seas, elevations range up to 5600 m and climate varies from moist, temperate in the west (1200–2000 mm precipitation) to arid in the east (<250 mm). Lowland natural vegetation ranges from steppes in the western plains to semi-deserts, and arid woodlands in the east. Mountains cover about 65% of the region and are dominated by broadleaf forests (mostly beech, oak, hornbeam, and chestnut) with some dark coniferous and pine forests (Krever et al., 2001), mountain meadows, and bare rock and ice. We selected the Caucasus ecoregion, as delineated by the World Wide Fund for Nature (WWF, Krever et al., 2001) as our study area (580000 km$^2$), plus a buffer of 25 km to avoid edge effects in the predictors (Fig. 1).

The exact historic range of European bison in the Caucasus is not known, but archeozoological findings suggest historic occurrences throughout the Greater Caucasus (Kuemmerle et al., 2012; Nemtsev et al., 2003; Sipko et al., 2010). Bison today occur in three reintroduced herds in Russian protected areas: the Caucasus biosphere nature reserve (Kavkasky, 830 animals, consisting of European bison × American bison (*Bison bison*) hybrids), Teberdinsky biosphere nature reserve (Teberdinsky, 22 animals), and the North-Ossetian national nature reserve (North Ossetia, 66 animals).

### 2.2. European bison presence data

We delineated the summer and winter ranges of the three existing populations, and a fourth that was extirpated by poachers near the city of Nalchik in the 1990s, based on information taken from the literature and our personal experience (co-authors T. Sipko, S. Trepet), and outlined them on topographic maps (1:25000) and high-resolution Google Earth images. The ranges represented 1160 km$^2$ of summer and 180 km$^2$ of winter habitat (Fig. 1). From these ranges, we randomly selected 50 location points per herd for summer and 30 location points per herd for winter grounds, while keeping a minimum distance of 500 m to avoid spatial autocorrelation. We further excluded locations on roads. In total, we used 195 locations for summer and 46 locations for winter habitat (not all ranges were large enough to contain 50 summer or 30 winter locations).

### 2.3. Predictor variables

To parameterize our habitat suitability models, we used a candidate set of eleven predictors characterizing landscape composition, topography, vegetation productivity, and human disturbance (Appendix A), out of which we included six environmental and two human-disturbance predictors in our final models (Table 1).

To capture land-cover, we used the 2009 Globcover dataset (300 m resolution, Bontemps et al., 2011, http://due.esrin.esa.int/globcover/). We aggregated the 22 Globcover land-cover categories into ten classes: coniferous forest, mixed forest, broadleaved forest, open forest, grass- and shrubland, cropland, mosaic vegetation/cropland, bare and sparsely vegetated areas, settlements, and water (for details see Appendix A). To capture forest fragmentation, we used morphological image segmentation applied to the combined forest classes as the focal class (Vogt et al., 2007). We stratified all forest gridcells into (i) core forest (forest neighbors), (ii) edge forest (outer margin of core forest), (iii) islet (forest patches too small to contain core forest), and (iv) perforation (interior edges, Kuemmerle et al., 2010; Vogt et al., 2007), using an eight-neighbor rule and 300-m edge width. We also calculated the Euclidean distance of each pixel to the closest forest edge. In addition, we acquired the Vegetation Continuous Fields product (VCF, MOD44B,