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Habitat Suitability Models, for ecological study of the alpine marmot in the central Italian Alps

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ABSTRACT

Habitat Suitability Models (HSMs) are central tools in physical and environmental planning because they are able to predict potential distribution of species. In this study two spatial methods were compared to define the HSM for *Marmota marmota* L. in the Adamello Brenta Nature Park in the Italian central southern part of the Alps. The first model was based on Weighted Linear Combination (WLC), a nonparametric overlay procedure, the second one was a parametric method based on logistic regression algorithm. Data collected in two sample areas were used to build the models, while data recorded along linear transects evenly distributed throughout the study area were used for testing the model performance. The models were validated calculating the Area Under the Curve (AUC) of the Relative Operating Characteristics (ROC). The two models had similar performances, but the accuracy of the WLC model was slightly higher than the logistic model (AUC of 0.833 instead of 0.821). The habitat preferences of *Marmota marmota* L. were also investigated with Jacobs index and chi-square test and compared with other studies in different environments. The results demonstrated that the relative importance of environmental factors for *Marmota marmota* L. changes depending on local conditions.

1. Introduction

1.1. The ecological preferences of Marmota marmota L.

Alpine marmot (*Marmota marmota* L. 1758) is spread through the Alps in France, Italy, Switzerland, Germany and Austria and isolated subpopulations are found in the Pyrenees, Massif Central, Jura, Vosges, Black Forest, Appenines, High Tatras, and Romanian Carpathians (Herrero et al., 2008). The alpine marmot is evenly distributed along the Alps although with variable density: 3 indiv/ha in the La Vanoise National Park, French Alps (Perrin et al., 1993), 1.18 indiv/ha in the Hautes Alps (Mann and Janeau, 1988), 1,03 indiv/ha (Lenti Boero, 1999) and 0.36 indiv/ha in the Gran Paradiso National Park (Bassano et al., 1992). The alpine marmot has been studied for decades for its interesting physiological, ethological and ecological characteristics (Borgo, 2003; Armitage, 2014). The marmot is a territorial species that lives in family groups consisting of one dominant adult couple, a variable number of sub-adults and the young of the year (Barash, 1989; Arnold, 1990; Perrin et al., 1993). The species spends most of its time in burrows which are therefore fundamental for its life-cycle (Barash, 1989; Mann et al., 1993). The "burrow system" is formed by the main burrow, the auxiliary burrow and the hibernation burrow, in which marmots spend the hibernation period. This "system" is a limiting factor for the spatial distribution of the marmot and its importance was emphasized in two ecological studies by Allainé et al. (1994) in the French Alps and by Lenti Boero (2001) in the Italian western Alps. The influence of environmental factors on marmot distribution was investigated by several scientists, leading to non-univocal results. Allainé et al. (1994) studied habitat preferences of marmot in two populations settled in the French Alps. The relative importance of environmental factors (slope, aspect, elevation, human disturbance) that influenced the species settlements in the two French populations, were different. More recent studies showed that grassland mixed with rocky habitats were positively selected in particular during the colonization of new territories (Giboulet, 2000; Borgo, 2003). Based on these findings, it looks evident that marmots are sensitive to a complex combination of factors, which have different importance in various conditions (Allainé et al., 1994). The first step to understand them is to evaluate all factors simultaneously, defining for each the used-available ratio (Allainé et al., 1994). Several ecological and ethological studies investigated the habitat preferences of marmot exploiting the territorial behavior of the species, in particular the presence of family groups and of the relative main

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burrow were considered. The habitat preferences of marmot were generally studied using the χ^2 test (Bassano et al., 1992; Allainé et al., 1994, Herrero et al., 1994; Giboulet, 2000; Borgo, 2003), the Fisher test (Allainé et al., 1994), the Bonferroni test (Herrero et al., 1994), and the ANOVA test (Borgo, 2003). In two studies conducted in the Italian Alps the Jacobs index was used (Jacobs, 1974; Borgo, 2003; Priori and Scaravelli, 2011) to detect which interval of environmental variable was positively selected and preferred by the species. Jacobs index ranged between +1 (positive selection) and −1 (negative selection) (Jacobs, 1974). The value of 0 indicates that the habitat was used in proportion to its availability.

1.2. Habitat Suitability Model

Animal-habitat relationships still represent the most widespread tools used by governmental agencies for spatial modeling (Guisan and Zimmermann, 2000; Gontier et al., 2010). Habitat Suitability Models (HSMs) relate field observations to a set of environmental variables that presumably represent one of the key factors of the ecological niche (Guisan and Zimmermann, 2000; Hirzel et al., 2006). HSMs were applied in conservation biology and developed in different contexts, from African mammals (Boitani et al., 2008), to caribou conservation in Canada (Leblond et al., 2014) and on endangered species conservation (Wilsey et al., 2012; Hamilton et al., 2015). They were also used in evaluation and management programs (Vospernik and Remoiser, 2008), as well as in environmental planning assessment (Gontier et al., 2010). Nowadays different methods are available and their choice depends mainly on availability of input data and on the study target (Guisan and Zimmermann, 2000). Two types of these modeling techniques are: i) methods based on presence/absence data, which assume that presence index indicates suitable areas for the species while absence data indicates unsuitable areas, and ii) methods based only on presence data when absence data are not available (e.g. for rare species) (Guisan and Zimmermann, 2000; Hirzel et al., 2006).

Presence/absence methods had a widespread use and an overview of the variety of techniques was proposed in particular by Guisan and Zimmermann (2000), but also in online text (Pearson, 2007) and in more recent review edited by Elith and Leathwick (2009). Presence only methods were developed more recently and an overview of the existing methods was presented by Phillips et al. (2006). Several methods are available to model species distribution (Guisan and Zimmermann, 2000; Elith and Leathwick (2009). Generalized Linear Models (GLMs), such as logistic regression, are the most used, starting from the first ecological modeling studies (Guisan and Zimmermann, 2000; Rutherford et al., 2007; Elith and Leathwick, 2009). Nowadays spatial models based on Geographic Information Systems (GIS) are increasingly used with the purpose to apply distribution models directly to spatial planning. The increasing availability of remote sensed data has widened the operational application of these techniques, see for example Graf et al. (2009), where LiDAR data were used for modeling habitat requirements of capercaillie (*Tetrao urogallus*) and thus supporting forest management approaches. Several statistical techniques are available to assess the performance of HSMs predictions (Guisan and Zimmermann, 2000; Guisan and Thuiller, 2005; Hirzel et al., 2006). The Receiver Operating Characteristic (ROC) and the measure of the Area Under the ROC Curve (AUC) have become very common procedures. However, recent studies have showed that ROC and AUC are a good evaluation criterion for presence/absence models, especially when it is possible to assume that the modeled species are in pseudo-equilibrium with their environment (Hirzel et al., 2006; Cianfrani et al., 2010).

At present there are only two studies regarding HSMs for the alpine marmot. Borgo (2003) used Discriminant Function Analysis (DFA) aimed at comparing the habitat saturation of two marmot populations and to evaluate the suitability of potential reintroduction areas. Lòpez et al. (2009) used Generalized Linear Models (GLMs) to detect the most significant variables influencing the presence of marmot. HSMs represented an important tool in order to understand why the species' density was variable and if it depended on certain environmental factors.

1.3. Aim of the study

The purpose of this study is to analyze which type of HSMs may better explain the habitat suitability of alpine marmot, and which environmental factors are more relevant for such purpose. In particular this study aims to (i) compare two multivariate GIS-based models for the alpine marmot in the Adamello Brenta Nature Park, (ii) to deepen the ecological knowledge of the species, and (iii) to produce a habitat suitability map for the marmot in the study area. In particular, we compared the Weighted Linear Combination (WLC) approach, a nonparametric type of fuzzy Multi-Criteria Evaluation (MCE) (Carver, 1991), against a more traditional parametric procedure based on logistic regression. WLC is a non-parametric simple procedures well established in GIS and then easy to apply within management programs because the result is a continuous mapping of suitability. Logistic regression is one of the earliest approaches to modeling species distribution where model extrapolation depends on a specific combination of variables. Two models, with different level of complexity, were compared to point out their flexibility and performance in assessing their relevance in management applications and ecological species studies.

The models were based on field observations and validated against independent observations, through the calculation of the ROC and AUC statistics.

2. Materials and methods

2.1. Study area

The study was conducted in the Adamello Brenta Nature Park (46°7′17″N, 10°45′8″E) in the south-western part of the Trentino-Alto Adige Region, in the Italian central southern part of the Alps (Fig. 1). The protected area is characterized by a high morphological, edaphic, flora and fauna diversity. The Park is 620 km^2 wide, covering two separate geomorphologic areas: the Brenta Dolomites range and the granite Adamello-Presanella range. The Brenta Dolomites are deeply modeled by karstification (that makes the area more dry), while on the other side, the Adamello-Presanella is characterized by glacial phenomena. The soils of the Brenta Dolomites have originated by carbonate rock and therefore are basic (Arrighetti, 1973). The Adamello-Presanella range is characterized by intrusive bedrock and therefore the soils are acid (Arrighetti, 1973). Altitude ranges between 600 and 3558 m, climate ranges between subalpine to continental and average yearly precipitation are 1100 mm. Bare rocks cover 26% of the Park, while the vegetation is dominated by coniferous forests (22%) and sparsely vegetated areas (15%) (EEA 2012). Other land covers are: natural grasslands (9%), moors and heathland (8%), transitional woodland-shrub (7%), coniferous/broad-leaves forest (6%), broad-leaved forest (3%), and glaciers and perpetual snow (3%) (EEA, 2012). Grasslands are mainly dominated by *Festuca* sp., *Carex* sp. and *Nardus* sp. on Adamello-Presanella range and by *Sesleria* sp., *Carex* sp., and *Poa* sp. on Brenta Dolomites range (Pedrotti, 1999).

2.2. Field data

Two independent field data sets were used: a training set to develop the models and a validation set to evaluate the prediction performance of the models.

The training set was obtained from a census conducted in sub-areas, one located in the Adamello-Presanella massif and the other one in the Brenta Dolomites range (the sum of the two areas account for 6996 ha, that is 11% of the study area) (Fig. 1).