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Research Paper

Moderately urbanized areas as a conservation opportunity for an endangered songbird

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ABSTRACT

Urban sprawl has increased in Western Europe principally due to conversion of farmland areas, which has constrained remaining farmland to more intensive use. Urban densification aims to counteract urban sprawl; however, it threatens urban green spaces that act as sustainable alternative habitats for wildlife. In this study, we used the Common Redstart (*Phoenicurus phoenicurus*) as a model species to develop sustainable planning recommendations for urban green spaces. Using species distribution models (SDMs) in combinations with high-resolution predicting variables (2×2 m grid cell), we defined the suitable habitat of a Common Redstart territory in a moderately urbanized environment. We then predicted how the distribution would be affected under realistic scenarios of land-use modification (termed conservation scenario and threat scenario) in an effort to provide recommendations for urban green space planning. Tree canopy cover was the principal land-cover type in the SDMs that explained the current species distribution followed by impervious surface and short-cut lawn. In the conservation scenario where tree canopy coverage was increased we predicted an increase in optimum habitat for the Common Redstart from 7% to 27% of the study area. In contrast, under a threat scenario based on urban densification, we predicted a decrease in the optimum habitat to only 4% of the study area. The SDMs results were used to highlight the importance of the suitable areas that have a predicted potential to conserve and promote an interconnected urban green space networks to maintain urban biodiversity.

1. Introduction

In Western Europe, urban sprawl has increased up to 80% since the 1950′s, largely due to broad-scale conversion of farmlands and agricultural areas (Antrop, 2004). Urbanization in Switzerland represents an extreme example, with an increase in urban areas of 125% between 1935 and 2002 (total surface cover of urban areas increased from 4000 km^2 to 9000 km^2; ARE, 2009b; Hayek, Jaeger, Schwick, Jarne, & Schuler, 2011). During the same period, agriculture has intensified in Western Europe, resulting in the loss and degradation of traditional farmland landscapes over large scales (Foley et al., 2005). Consequently, many previously widespread farmland bird species have lost suitable habitat and have shown considerable range and population declines (Donald, Green, & Heath, 2001; Donald, Sanderson, Burfield, & van Bommel, 2006). In this context, moderately urbanized areas (i.e. sparsely housed areas) with a heterogeneous landscape composed of green spaces (e.g. private gardens and parks) and man-made structures could offer alternative habitats for many wildlife species (Aronson et al., 2014; Ives et al., 2016).

Developing sustainable urban green spaces for conserving native biodiversity and its ecosystem services (according to e.g. URBIO criteria; Müller, Elsner, & Wittmann, 2014) could be undertaken at two different spatial scales: small (i.e. garden and park) versus large spatial extent (i.e. city; Goddard, Dougill, & Benton, 2010). At the local scale, providing a combination of land-cover types within a given bird territory should create suitable habitats and meet resource requirements which is critical for conservation (Daniels & Kirkpatrick, 2006). At the landscape scale, interconnected networks of suitable habitats improve the viability of populations (Douglas & Sadler, 2011). Because urbanized environments are usually

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highly fragmented (Grimm et al., 2008), management effort to build green space networks is needed to support biodiversity (Lepczyk et al., 2017). However, many urban land-use planning strategies in Europe currently seek to mitigate urban sprawl by urban densification (ARE, 2009a; Fatone, Conticelli, & Tondelli, 2011; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006). For example, the city of Stockholm aims to increase the density of constructed impervious surfaces during its expected urban sprawl from 2000 to 2050, which will correspond to 90-km^2 of constructed impervious surface (Schmitt & Schlossman, 2012). Such land-use planning will obviously reduce urban green space and therefore involve trade-offs between future human use (i.e., urban densification) and biodiversity conservation (i.e., maintaining urban green space; Aronson et al., 2017). In the near future, urban sprawl and urban densification will constitute two opposite scenarios for the expansion of cities and will lead to different urban green space management to minimize their impacts on native biodiversity. Land-sharing vs. land-sparing concepts have been proposed as two contrasting urban green space management strategies to maximise urban biodiversity (Soga, Yamaura, Koike, & Gaston, 2014; Stott, Soga, Inger, & Gaston, 2015). In land-sharing, low density constructed impervious surfaces will be interspersed with green spaces (i.e. garden and park) but will lack large continuous green patch. Alternatively, in land-sparing, high density constructed impervious surfaces will have large continuous green spaces. These two concepts could be associate with vertical green infrastructure, such as green wall and roof garden, who may provide additional green spaces for biodiversity (Collins, Schaafsma, & Hudson, 2017). To date, understanding variations in and ecological aspects of intra-urban biodiversity has been obtained by comparing habitat variables within cities (Beninde, Veith, & Hochkirch, 2015), but no predictions have been made on how species distributions will be affected by future urban land-use scenarios.

In this study, we used the Common Redstart (*Phoenicurus phoenicurus*) as a model species to spatially define sustainable urban green space. We posited that the habitat suitability of the Common Redstart could serve as an indicator for sustainable urban green space due to the multiple ecological requirements of this bird (see A1. Table S.1). From a conservation point of view, the Common Redstart is a species of conservation concern in Switzerland and other countries in Central Europe (BirdLife International, 2004; Spaar, Ayé, Zbinden, & Rehsteiner, 2012). The Common Redstart was originally found in semi-open areas such as orchards and woodland edges. However, in areas where changes from semi-open areas to rural landscapes have occured, Common Redstart populations in urbanized areas have become of higher relative importance. Nowadays, monitoring programs and regional atlas projects in Europe estimate that between 17 and 59% of Common Redstart populations are located in urbanized areas (Droz, Arnoux, Rey, Bohnenstengel, & Laesser, 2015). This large variation is likely due to non-homogenous land conversion changes across Europe (Verburg & Overmars, 2009).

In this study, we therefore address the following two questions: (1) what is the combination of environmental factors that best defines the suitable habitat of a Common Redstart territory in an urbanized environment?, and (2) how will these suitable habitat conditions be geographically affected under two realistic and contrasting future land-use scenarios? The first question has been qualitatively assessed in term of land-cover (Droz et al., 2015; Fontana, Sattler, Bontadina, & Moretti, 2011; Sedlacek, Fuchs, & Exnerova, 2004), however, the relative importance of topo-climatic environmental factors and the most suitable proportion of each land-cover surfaces within a territory remains to be known. The second question is key to prioritize urban areas and balance future urban development strategies between land-sparing and land-sharing. To address these two questions, we used a collection of species distribution models (SDMs) in combination with high-resolution predicting variables (2 × 2 m grid cell) to analyze data obtained from a medium-sized town in Switzerland. By modelling the habitat of an indicator species and simulating realistic land-use scenarios, our aim was to provide clear recommendations to local authorities and urban planners on management strategies needed to promote and conserve an interconnected urban green space network and thereby biodiversity.

2. Material and methods

Our methodological concept consisted of five steps (Fig. 1). First, species data were acquired and predicting variables were identified as

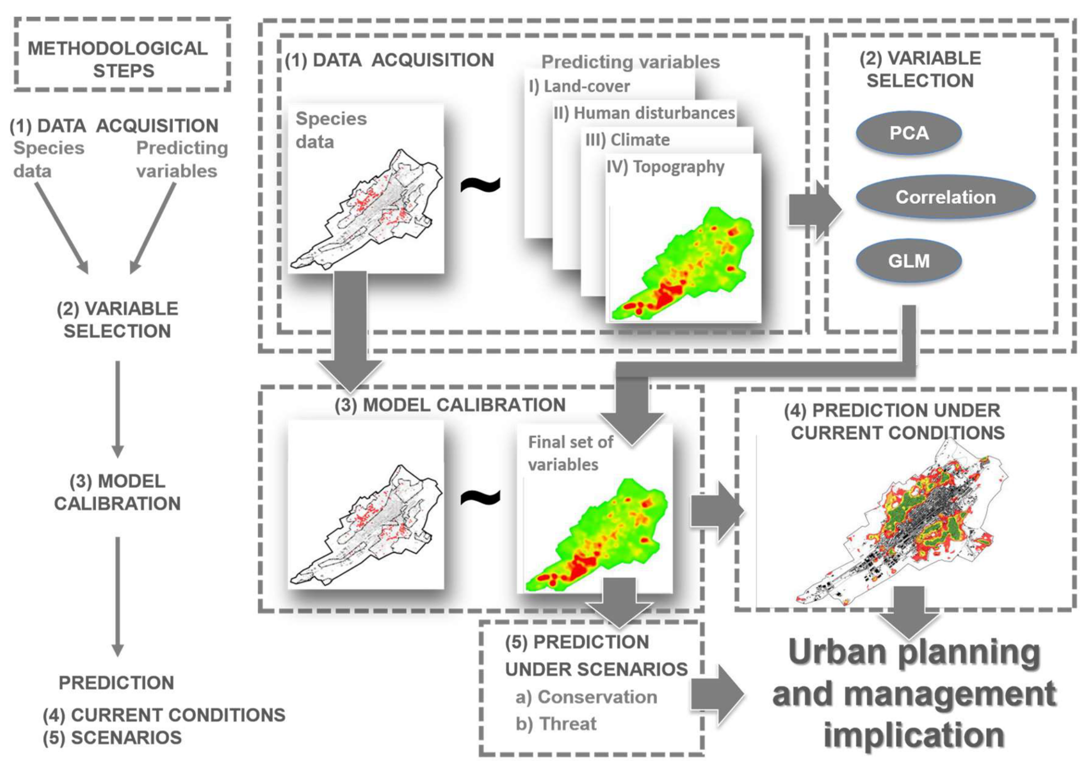

Fig. 1. Conceptual chart summarizing methods. Numbers in the figure correspond to the chapters in the material and method section. PCA refers to principal components analysis, correlation refers to Pearson's correlation coefficients between predicting variables, and GLM refers to univariate generalized linear models.