Quantifying the vulnerability of *Lacerta agilis* to invasive *Podarcis muralis* encroachment in Salzburg, Austria

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Aim **The aim of this study is to develop a modelling workflow to identify if and where there are areas of conceivable conservation concern regarding to the native Sand Lizard due to possible encroachment of the introduced Wall Lizard.**

Introduction

The effect of invasive species on ecosystems is among the five biggest drivers of change, that have a large impact on ecosystem services and biodiversity (Díaz et al. 2019) and thereby on the lives of many people around the world. What determines the final result of biological invasion is the interspecific competition between native and introduced species (Parker et al. 2006).

We deal with two possibly competing species, one is native to Salzburg (*Lacerta agilis*, the Sand Lizard) and the other one was introduced by transport systems (*Podarcis muralis*, the Wall Lizard). The Wall Lizard is native to many parts of Europe, but so far also has established more than 150 non-native populations in Central Europe, and also other parts of the world (Schulte et al. 2012; Michaelides et al. 2015). The first allochthonous population in Salzburg became known in 2008 (Maletzky et al. 2011) at a railway station in the north of the province. Two further populations were detected in 2014 and 2015 at the railway in the city of Salzburg and at the railway station in Schwarzach and two more in the villages Elsbethen and Schwöll (Niedrist et al. 2020).

Material and Methods

Study area and occurence records:

- Federal state of Salzburg, Austria, in Central Europe
- Occurrence data for both species: "Herpetofaunistische Datenbank des Hauses der Natur, Salzburg", retrieved on 22 04 2021

Variables:

- Initial set of 15 variables, resampled to a resolution of 30m x 30m (QGIS 3.16.5)
- Accounting for the ecological niche and functional relation in geographic space we calculated landscape level landscape metrics with the moving window method (Hagen-Zanker 2016) and the R package "landscapemetrics" (Hesselbarth et al. 2019) as predictor variables.

Modelling Workflow:

BART ⇨ Favourability Model ⇨ Biotic Threat Calculation ⇨ Source and Sink Areas ⇨ Cost-Distance-Model

Model building:

- Bayesian Additive Regression Trees (BART), producing presence probability as input for subsequent calculation of the favourability models (Acevedo, Real 2012).
- Selection of appropriate predictor variables prior to model building for each district and both species, using the "variable.step" function of the "embarcadero" R package (Carlson 2020).

Model evaluation: We partitioned the data initially in five-fold cross validation sets. All grid cells of the respective district were split into five groups (folds) with the R package "BlockCV" (Valavi et al. 2018). The size of the blocks was 10 km x 10 km. To account for different areas of model performance measurement, we used three complementary evaluation metrics and integrated them into the model selection process (TSS, MCS, AUC).

Results

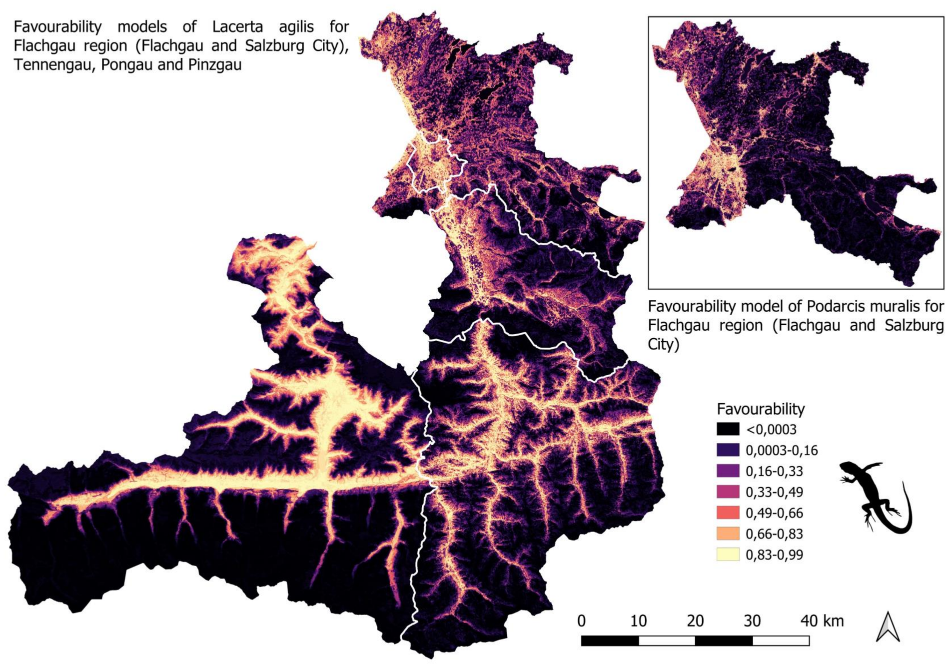

Figure 1: Favourability model for *Lacerta agilis* (Salzburg except Lungau). For *Podarcis muralis* a significant model could only be obtained for the Flachgau region (Flachgau and Salzburg City) (Lizards.svg: Plank 2010) .

We were able to generate significant distribution models for *Lacerta agilis* for all districts except the Lungau, for which only 26 occurrence records were available. For *Podarcis muralis* we could only obtain a significant model for the Flachgau region (Fig. 1).

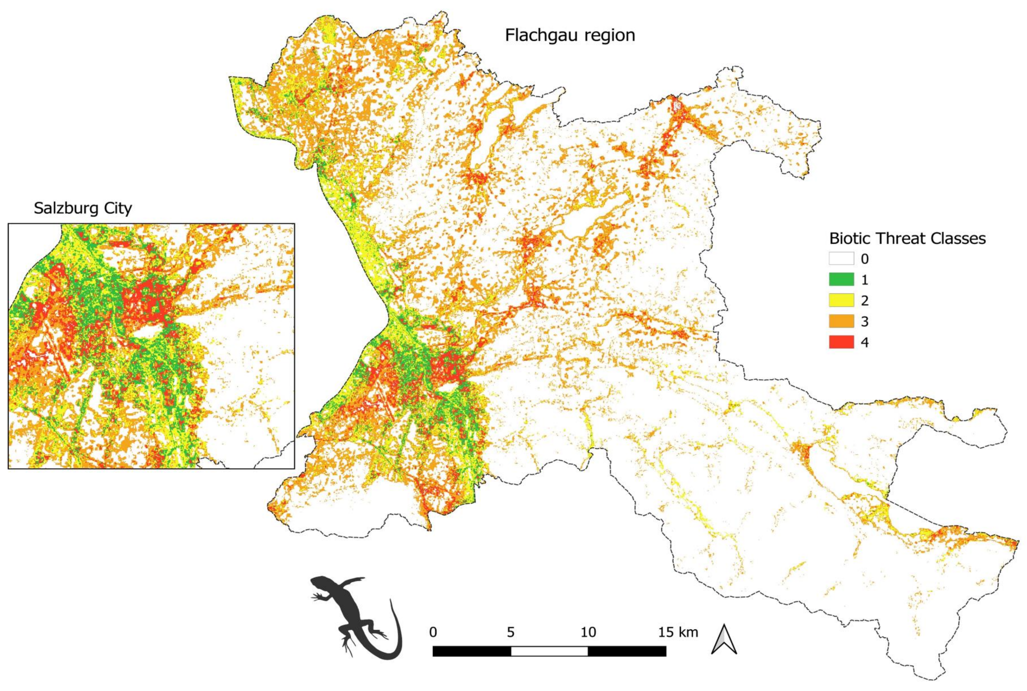

Figure 2: Distribution of biotic threat classes (Muñoz, Real 2006): 0 (white) low favourability for at least one species, so no biotic threat applies (abiotic exclusion). 1 (green) high favourability for both species, so co-occurrence should be possible and biotic threat is low (sympatric coexistence). 2 (yellow) favourability is high for the proposed weaker species and intermediate for the stronger species, what makes the level of threat moderate. 3 (orange) intermediate favourability for both species, so the proposed stronger species succeeds and the level of threat for the weaker species is high. 4 (red) favourability for the stronger species is high and only intermediate for the weaker species what makes the level of threat very high for the weaker species (biotic exclusion) (Barbosa 2015) (Lizards.svg: Plank 2010) .

Figure 2 shows the biotic threat classes for the Flachgau region and therefore contains information about possible conflict areas of both species. *P. muralis* was supposed to be the stronger species and *L. agilis* the weaker species.

The output of the source and sink area calculation confirmed that most of the occurrence records of *L. agilis* and *P. muralis* are situated in areas with high favourability. In the Pinzgau, 95.5% of the *Lacerta agilis* records are sources and only 0.8% were classified as sinks. In Pongau, 88.9% of the *L. agilis* records are sources and 1.4% are sinks. When examining the Tennengau, 87.4% of the *L. agilis* records are sources and 4.5% are sinks. In the Flachgau region for *Lacerta agilis* only 74.3% of the occurrences are sources and 5.5% are sinks.

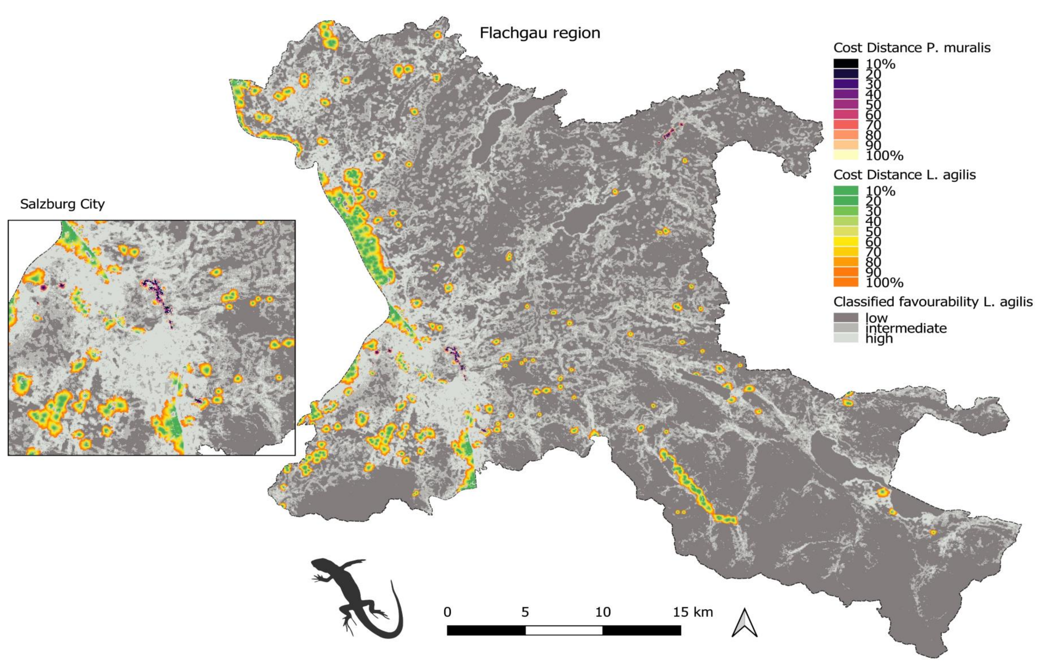

Figure 3: Cost-distance-model. None of the outputs reached the maximum distance of 800 m for L. agilis or 500 m for P. muralis. The output distances in relation to environmental resistance for movement seem to be concordant with our field observations of the movement abilities of these two species. (Lizards.svg: Plank 2010)

The Cost-Distance-Model shows the connected source and sink areas for *Lacerta agilis* and *Podarcis muralis* in the Flachgau region. *Podarcis muralis* only interferes with *Lacerta agilis* in the city of Salzburg and in the south of the city (Figure 3).

Conclusion

To assess the risk exposure for one species the proposed modelling workflow seems to be appropriate to picture more than just one aspect of the many risks populations are prone to. With the favourability model the areas that are suitable for habitation of a species can be quantified and mapped onto the potential distribution range. With the biotic threat assessment, the interplay between two species and the potential problematic areas in geographic space can be displayed. Only when also considering the source and sink cost-distance model, propagation obstacles or the intrusion of other species can be determined. The quality of the model output strongly depends on the quality of the input data. For small species with limited propagation ability predictor variables with higher thematic grain would be desirable, given the data accuracy is also high. Finally, it must be highlighted that the outlined workflow can only illustrate one point in time. Therefore, the modelling process should be repeated on a regular basis. We propose a five-year interval to keep up to date with population development and environmental changes. Due to the low number of *Podarcis muralis* in Salzburg so far, only a very moderate risk for *Lacerta agilis* could be detected.

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