# Critical thresholds as a basis for favourable reference area in grassland habitats

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## Introduction

Favourable reference values can be assessed according to two approaches: a model-based approach and a reference-based approach. Here, I present a model that estimates habitat threshold values for semi-natural grassland specialist species in Sweden. Such thresholds may form the basis for a reference-based approach to assess reference values for habitat area. However, it is suggested that assessments are also compared to historical records of habitat land cover and location.

The approach is partly based on two reports that recount potential methods to assess favourable reference areas for terrestrial habitats drafted by the SLU Swedish Species Information Centre on commission by the Swedish Environmental Protection Agency (Toräng & Berglund 2019, Toräng 2020), and partly on a habitat threshold model developed by researchers at Linköping University in a project financed by the Swedish Board of Agriculture (Bergman et al. 2022).

## Background

Land-use changes during the 20th century, including the cessation of traditional grassland management, have resulted in a tremendous decline of semi-natural grassland habitats, and a parallel loss of biodiversity (Chamberlain et al. 2000, Luoto et al. 2003, Öckinger & Smith 2006, Jiang et al. 2013, Cousins et al. 2015, Hooftman et al. 2016). The high number of threatened species (Eide et al. 2020), and the magnitude of present extinction debts (Helm et al. 2006, Cousins 2009, Krauss et al. 2010, Auffret et al. 2018) in semi-natural grasslands indicate that the extant amount of these habitats is too small to ensure the long-term viability of associated biodiversity. It is therefore necessary to re-establish functional habitat networks with sufficient area, quality, and connectivity, so that local populations of focal species can be maintained (Pärtel et al. 2005, Manton & Angelstam 2018).

One way to evaluate how much habitat that is needed for functional habitat networks is to identify relationships between the long-term maintenance of focal species and the critical amount of habitat, assuming that the probability of population persistence is rapidly reduced if the amount of habitat drops below a critical limit (Andersson et al. 2015, 2019, Manton & Angelstam 2018). These limits are species specific and represent minimum area requirements (MAR), i.e. the smallest habitat area needed to sustain viable populations (Baguette & Stevens 2013, Pe’er et al. 2014). A survey of the current scientific literature suggested that it is difficult to specify generic conservation targets in semi-natural grasslands based on habitat thresholds, even though several studies agrees on that at least 10% of the land cover is required for the long term maintenance of several species (Toräng 2020, Cousins et al. 2022).

## Methodology

### Modeling critical thresholds for species persistence

The area of different types of grasslands within 409 3x3 km landscape quadrats were assessed from aerial photos as a part of the Remiil monitoring program (Lundin et al. 2016). Grassland habitat specialists may utilize many different types of grasslands but their relative importance for species viability varies depending on habitat characteristics such as current management, land-use history, and soil type. To accommodate for this variation in the habitat threshold model, the area of the different grassland types were weighted to reflect their relative importance for grassland habitat specialists, and for each of the 409 landscape quadrats, a total weighted area was thus calculated (Bergman et al 2022).

To examine the relationship between the amount of grassland habitat and the occurrence of grassland specialist species, species observation data was extracted from several sources, including data from both systematic inventories and the Swedish Species Observation System that includes spontaneously reported observations by volunteers. Binomial regression models were used to explore relationships between species occurrence and grassland habitat area, and to identify thresholds for individual species. In total, the models included more than 34 000 species observations, and thresholds were estimated for 221 species of plants, butterflies, and bees (Bergman et al. 2022).

Most species showed a positive relationship between grassland habitat area and the probability of occurrence. In addition, significant thresholds were identified for several species, varying from a few percent up to 20% grassland habitat area, even though thresholds within the range 5-15% habitat area were most commonly observed (Bergman et al. 2022). Comparable results were found in models using similar data but with a Bayesian statistical approach (Toräng & Stephan 2021).

### Limitations

Significant correlations between population persistence and habitat area may reflect historical processes that have been lost in the modern landscape, and if so, should only be interpreted with caution. One approach to explore the possible influence of historical population processes and present day species occupancy would be to compare the present models with models where the habitat amount is quantified from historical records of grassland cover.

In addition, most of the surveyed quadrats contained small areas of grassland habitat, and less than what is expected to be required for the long-term maintenance of many of the study species. It is therefore likely that several reported occurrences (especially for plants) were present due to time delays before local populations go extinct (i.e. extinction debt, Hanski & Ovaskainen 2002). If so, modelled thresholds would underestimate true breaking points for critical habitat amount.

Finally, it is important to consider whether the geographical scale of the study is relevant for the spatial ecology of the study species. The present study is limited by the spatial scale used in the monitoring program from which data was extracted and this constraint is difficult to overcome.

### Comparison to other studies

Even though thresholds are dependent on the scale of study, and varies among species and habitats, the results from the modelling reported here agrees with several published studies of area requirements among grassland specialists (reviewed by Toräng 2020), in that many species seem to require that at least 10% of the landscape area is covered by functional grassland habitat.

## Conclusions

Models of species persistence as a function of habitat area that are based on empirical data will almost certainly be limited by spatial scale. Given that favourable reference areas should be specified for biogeographical regions, it is therefore required that the results from such models are extrapolated to the biogeographical or national scale with caution. In a draft for Guidelines on concepts and definitions for the next Article 17 reporting (DG Environment 2022), it is suggested that the assessment of favorable reference area for many semi-natural habitats “*may require a combination of reference-based and area-based approaches”*. Thus, comparisons of benchmark estimates from models of required habitat area with historical records of land cover and location, may be a promising approach for the assessment of justifiable reference areas of grassland habitats.

The present models cover the total amount of grassland area in the landscape. Given that several of the semi-natural grassland types in the Habitats Directive are ecologically quite similar and many of the study species inhabit several habitat types, this should be the realistic approach. Identified thresholds thus reflect the total semi-natural grassland area required. However, to inform how such thresholds may be allocated to separate favourable reference areas specific for each Natura 2000 habitat type, other sources of data are necessary.

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