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Landscape history improves detection of marginal habitats on semi-natural grasslands

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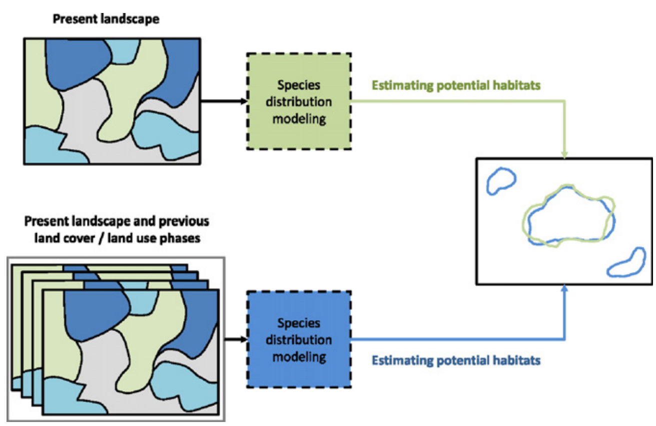
HIGHLIGHTS

- We modeled Fumewort distribution, indicating valuable semi-natural grasslands.
- Different models combining present and past landscape variables were built.
- Variables of present landscapes discern core habitats reasonably well.
- Historical data improves model performance substantially.
- Past landscape phases help in finding scattered marginal habitats.

GRAPHICAL ABSTRACT



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ABSTRACT

Semi-natural grassland habitats have markedly declined from their historical coverage, thus causing substantial losses for agricultural biodiversity and establishing a consequent need to spot the remaining habitat patches. These patches are generally remnants of once larger habitat areas, formed by uninterrupted and low-intensity management for centuries, but then later being isolated and fragmented into smaller pieces. In the light of this development, past landscape phases have a crucial role for the present existence of semi-natural grasslands. The importance of historical factors has been indicated in many studies but evaluation of their added value, or actual site-specific effects compared to observations of only the present landscape characteristics, is not generally provided. As data related to the past is often difficult to obtain, tedious to process and challenging to interpret, assessment of its advantages and related effects – or consequences of potential exclusion – would be needed.
In this study, we used maximum entropy approach to model the distribution of Fumewort (*Corydalis solida*) which in the study area is a good indicator of valuable semi-natural habitats. We constructed three different models – one based on only the contemporary environment with expected indicators of habitat stability, one solely on the historical landscape phases and long-term dynamics, and one combining variables from the past and the present. Predictions of the three models were validated and compared with each other, followed by an

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analysis indicating the similarity of model results with known Fumewort occurrences. Our results indicate that present landscapes may provide workable surrogates to delineate larger core habitats, but utilization of historical data markedly improves the detection of small outlying patches. These conclusions emphasize the importance of previous landscape phases particularly in detecting marginal semi-natural grassland habitats, existing in contemporarily suboptimal conditions and being prone to disappear if no further actions are taken.

1. Introduction

European agricultural landscapes have, during the last centuries, been under a considerable shift, driven mainly by technological progress and the aim to establish nationally and internationally competitive agricultural production (Busch, 2006). This change, characterized by both land use intensification and abandonment processes, has resulted in a loss of agricultural biodiversity and created an urgent need to explore its associated impacts on the environment (Strijker, 2005; Reidsma et al., 2006; Verburg et al., 2006). The decline of extensively managed semi-natural grasslands has been particularly widespread. These grasslands once formed a large network of species-rich habitats but nowadays mostly found only as scattered and small fragments (Kull and Zobel, 1991; Cousins and Eriksson, 2002; Johansson et al., 2008). Such grasslands require a long time and continuous but non-intensive management to develop and once this continuum is broken, habitat conditions deteriorate rapidly (Busch, 2006; Reitalu et al., 2010). As restoration or re-creation of semi-natural grasslands is a laborious and costly practice, the remaining patches of good habitat quality should be recognized as accurately as possible to promote their functionally viable network (Rydgren et al., 2010; Pitkänen et al., 2014). Fragmentary habitat structure however poses challenges for detecting the ecologically important patches, particularly because network connectivity relies partly on the small, separate, and easily ignored fragments (Cousins, 2006; Lindborg et al., 2008).

Recognition of valuable and well-preserved semi-natural grasslands is usually linked to finding certain indicator species (Andersson, 2012). While species distribution is generally expected to be determined by underlying climatic, land cover, land use and topographic characteristics (Molloy et al., 2014; Tian et al., 2014; Zank et al., 2014), the legacy of the previous landscape phases is also highly important for semi-natural grassland species. This perspective, however, is sometimes neglected due to various reasons. Firstly, changes may not be recognized in respect to the target species or period of observation due to the scarcity of information, distorted memories of the past (Marcucci, 2000) or unrealistic belief in undisturbed ecosystems (Christensen, 1989). Secondly, changes in the landscape may be identified but their importance is considered to be only minor, which can be correct on a regional community level but does not necessarily apply to local species distributions or habitat patterns (Parody et al., 2001). Thirdly, past changes as well as their importance may be understood but historical spatial data is too brief or fragmentary to use, or not obtainable for the structure of interest (Swetnam et al., 1999).

Applying a retrospective view however enables to find habitat patterns that, at present, may not be highly favorable but partly reflect their past characteristics due to the long generation times of plants, their slow responses to landscape changes and lack of an immediate ability to search for an alternative habitat (Orians and Wittenberger, 1991; Burel, 1993; Helm et al., 2006; Käyhkö and Skånes, 2006; Kuussaari et al., 2009). In terms of semi-natural grasslands, previous management intensity is one of the key factors for species distribution and once traditional practices have been abandoned, the remaining plant populations have started to become isolated with no guarantee of their long-term persistence (Cousins and Eriksson, 2001; Reitalu et al., 2010). Part of these former semi-natural grasslands, currently under a successional transition, may still be reverted to their previous stage if no crucial thresholds have been surpassed thus leading to another virtually irreversible state (Briske et al., 2005; Bestelmeyer et al., 2009).

In order to associate species distributions with their environmental determinants, distribution models have been used enabling predictions based on spatial data and observed species occurrences (Guisan and Zimmermann, 2000; Jiménez-Valverde et al., 2008; Elith and Graham, 2009). Models can also be constructed to include history-related variables and change dynamics, which have often been found highly important both for species distribution or their richness (Ficetola et al., 2010; Brudvig and Damschen, 2011; Bommarco et al., 2014). Depending on the method used, a model may require both presence and absence observations, or rely only on presence data. Presence-only models favor the fact that absence data is not always available, being derived from the applied observation strategy, unreliably detected true absences or utilization of existing data sets that contain only positive detections (Raes and ter Steege, 2007; Crawford and Hoagland, 2009; Stokland et al., 2011); however they also pose restrictions for validation procedures due to the lack of known absences. While construction and interpretation of the models is relatively easy, their evaluation is usually restricted to observing model coefficients and related statistics without comparative approaches. This strategy is able to indicate the most influential model factors but generally lacks possibilities to detect their detailed and site-specific effects, or check results against alternative models with a different set of predictors. In addition, when having only presence observations for building and validating the model, performance can only be assessed as a separation between the observed presences and background data without knowledge of any potential biases (Phillips et al., 2009).

In this paper we apply the maximum entropy approach, being one of the most widely used contemporary modeling techniques, to associate the distribution of Fumewort (*Corydalis solida*) with its environmental determinants. Fumewort is favored by the long-term presence of open or partly open grazed semi-natural grasslands in the study area, and forms extensive occurrences only in favorable places. We built three different models using carefully selected environmental variables: one based only on contemporary environment with expected surrogates of habitat stability, one solely on the historical landscape phases and long-term dynamics, and one combining the variables from the past and the present environmental conditions. These three models were validated using independent presence/absence data and their performances were compared. Furthermore, locations predicted to contain probable Fumewort occurrences were evaluated in respect of the model performance, in order to indicate their environmental determinants at a detailed level and reflect the actual effects of knowing the landscape history on the prediction results. More specifically, the aims of the study are:

1) To construct, apply and evaluate different models for the distribution of Fumewort;
2) To identify the site-specific effects of present ecological determinants as well as the influence of past landscapes and change trajectories; and
3) To discuss the advantages of historical data in providing habitat details relevant for the needs of spatial planning and biodiversity protection in semi-natural landscapes.