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Predicting the distribution of forest habitat types using indicator species to facilitate systematic conservation planning

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ABSTRACT

Recent assessments have identified significant shortfalls in the current Natura 2000 network approach for identifying protected areas throughout the European Union. A more systematic conservation network planning approach that adopts strategic development options and considers the occurrences of species and habitats within the distribution ranges of species across larger areas is needed in order to support decision making processes on the potential expansion, establishment and/or maintenance of conservation areas. Using high-nature-value forest habitats across a large test region, i.e. the state of Lower Saxony in Germany, we developed a method aimed at systematically locating and appraising temperate forest habitats using indicator species distribution maps. Forest community indicator species were determined using forest habitat affinity criteria (derived from an existing database) and community fidelity (based on a review of 5338 vegetation relevés). Known habitat occurrences were derived from habitat surveys and relevant literature and were related to model data on indicator species distribution on a grid of 1739 raster cells (each 30 km^2) using logistic regression. The predictive power of the distribution models increased with the number of indicator species. However, tight correlations between indicator species distribution and habitat occurrence were only found when indicator species with a high affinity to forests were used exclusively. Field inspection of grid cells with outlying occurrences of five upland forest communities revealed several new forest habitat locations and led to greatly improved distribution models. We conclude that the distribution of high-nature-value forest habitats can be predicted from large-scale raster data on plant species distributions when only indicator species with close association to forest habitats and a high fidelity to a single community are selected. Our approach may therefore facilitate a review of the existing Natura 2000 forest conservation network, be used to identify additional conservation areas or to monitor the success of forest conservation management measures.

1. Introduction

The European Union Habitats Directive (Council Directive 92/43/EEC) has successfully promoted nature conservation across Europe for the last 20 years. The Natura 2000 network of nature protection areas, established with the aim of halting biodiversity loss, is now approaching completion for the terrestrial area of the European Union (EU). Despite these efforts, the 2010 target to efficiently protect habitats and species in Europe has not been reached (European Commission, 2011). One of the reasons of failure is that the selection of Natura 2000 areas has mostly not been based on systematic conservation planning; this conclusion was recently drawn for the situation in Germany by Jedicke (2012). Reviewing the planning and implementation processes in European protected areas, Gaston et al. (2008) came to the conclusion that, although the Natura 2000 process has been undoubtedly the most important attempt to select additional protected areas across Europe,

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the program did not really exploit the benefits that a systematic conservation planning approach could have brought. A systematic approach would adopt strategic development options and would consider locations of ecologically valuable habitats within the distribution ranges of the species and habitats beyond the existing Natura 2000 network of protected areas (as proposed by European Commission, 2006). By addressing these deficits, the EU Biodiversity Strategy to 2020 has formulated the goal of integrating species and habitat protection into key land use policies both within and outside the existing Natura 2000 areas (European Commission, 2011). This target will likely result in the need to identify additional areas outside the protected areas where valuable habitats are present with reference to Annex I of the Habitats Directive.

Localising additional habitats with high ecological value may often be problematic, because adequate information is widely lacking. Bunce et al. (2013) concluded that there are still many gaps in the inventory of ecologically valuable habitats in Europe. For example, the report of the German government to the European Commission on the implementation of the Habitats Directive for the period 2001–2006 assessed the quality of information needed to demarcate additional prospective nature protection areas as only moderate or poor (GNR, 2007). In many regions, extensive field surveys in the distribution of indicator species for high-nature-value habitats would be needed that are costly and time-consuming, but have been done in countries such as the Czech Republic (Chytrý et al., 2001) and Spain (Araújo et al., 2007). A possible practical solution to fill this information gap on the distribution of potential conservation areas in Europe is offered by models that predict habitat distributions using species range maps combined with auxiliary data on the occurrence of soil types, land cover and other indicative parameters (Mücher et al., 2009). Another possible option are high resolution remote sensing techniques that can be employed for habitat mapping and for distinguishing habitat types even with relatively low levels of contrast (Nagendra et al., 2013). Remote sensing has been used for mapping the extent of forest cover and tree communities by identifying canopy trees to species or genus level (e.g. Bunting et al., 2010; Dickinson et al., 2013). The extent and degradation state of semi-natural habitats can precisely be mapped and monitored using satellite data as shown for Wales, UK (Lucas et al., 2011). Remote sensing may be less useful, however, in the case of the broad-leaved forests of temperate Europe as considered in the Habitats Directive. They are characterised by only few tree species but primarily by the herb layer which cannot be identified by remote sensing techniques. Although plant species mapping programs with sufficient spatial resolution have been undertaken for a number of states in Germany and other Central European countries, knowledge on the distribution of the associated high-nature-value habitats is often less complete.

Systematic conservation planning requires clear decisions to be made on the features used as indicators of overall biodiversity (Margules and Pressey, 2000). While species distribution data provide valuable basic information for conservation planning, the recording of data on community distribution allows for the inclusion of aspects of ecosystem functioning in the planning of protected area networks. In the conservation agenda of the EU, habitat types are defined on the basis of vegetation description and the presence of characteristic syntaxa, but also with reference to certain abiotic features and the occurrence of characteristic plant and animal species. Thus, the EU approach largely adopts the methods of vegetation classification (Evans, 2010). The Interpretation Manual of European Habitats (European Commission, 2013) lists a number of characteristic species for each habitat type. However, this procedure is constrained by the often large differences recorded between regions and countries in the usage of indicator species and, consequently, in the interpretation of habitat types (Evans, 2010). A worked example on Central European

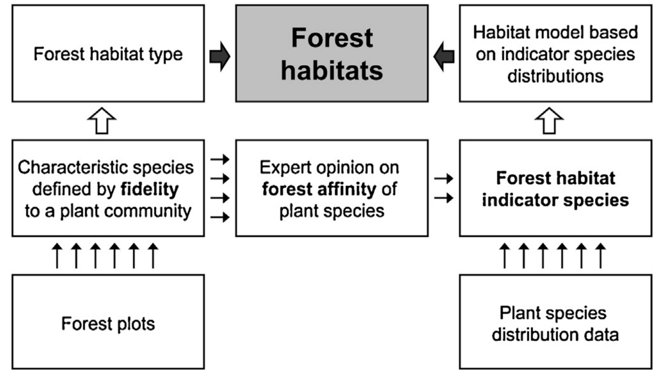

Fig. 1. Flow diagram depicting the approach for predicting Natura 2000 forest habitats from forest community distribution models based on raster maps of the distribution of indicator species. Indicator species are derived from phytosociological classification (fidelity of characteristic species to a forest community), narrowed to species with high forest affinity (based on expert opinion).

spruce forests by Chytrý et al. (2002a) discloses that variation in the interpretation of plant communities depends on the underlying dataset on which the delimitation of characteristic species is based. First of all, it may range from a local scale to a large area, and, correspondingly, the ranges of species available for classification vary. Secondly, the definition of indicator species is dependent on the scope of the planned comparison of habitats and communities, either leading to the selection of characteristic species within a narrowly delimited forest community or within a synopsis of forest habitat types, or in the definition of species suitable for differentiating a forest community from other non-forest habitats. Criteria for defining indicator species should therefore be adapted to the specific context on national or regional scales.

Bunce et al. (2013) highlighted that habitats and communities and their spatial distribution may serve as valuable indicators of the biodiversity of a region and presented a selection of characteristic species for the forest habitat types listed in the EU Habitats Directive that were taken from the Interpretation Manual. However, they suggested that the species lists should be supported by more detailed studies on the behaviour of the target species in different habitats, a recommendation which served as a starting point for our study. Using the German Federal State of Lower Saxony as a worked example of a large model region, we developed a method for facilitating the systematic localisation and assessment of forest habitats listed in Annex I of the Habitats Directive. We focussed on forest habitats because forests cover more than 90% of the area of Central Europe in terms of the potential natural vegetation and they are one of the most distinctive components of European nature today. However, the conservation value of European forests is continuously declining (EEA, 2010) and increasing effort is needed to identify high-nature-value forests and to complete the Natura 2000 network.

Our approach of completing existing habitat distribution maps of forest communities is based on vegetation classification, with forest communities (and the corresponding Annex I habitat types) being characterised as having a certain number of plant species that correspond to the forest community (Fig. 1). While characteristic species are derived from the classification of vegetation plots, a surveyed vegetation stand may likewise be assigned to a plant community based on the presence of diagnostic species. We hypothesised that the co-occurrence of several diagnostic species of a community within a grid cell of a plant distribution map should represent a strong indicator of the presence of that community in the cell. To make the approach work, we had to refine the indicator species concept from its use in classical phytosociology, because many species that are characteristic for a given forest association