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Original Articles

Test of the efficiency of environmental surrogates for the conservation prioritization of ponds based on macrophytes

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ABSTRACT

Ponds are recognized as habitats of high biodiversity hosting many threatened freshwater species. They comprise a major part of the continental waters in Europe. Conservation strategies for abundant habitats like ponds inevitably call for the prioritization of the sites with the highest conservation value. In conservation planning, environmental surrogates are frequently used as proxies, providing readily available environmental information that adequately represents the biodiversity features of target systems. However, environmental surrogacy has mostly been tested in the terrestrial realm. Here, we provide a first attempt to test the efficiency of environmental surrogates for the conservation prioritization of pond communities. Native and alien helophytes and hydrophytes were surveyed in 92 ponds in Central Europe. We combined the flexible regression tree approach with predictive modelling to test the efficiency of local and regional environmental surrogates in targeting pond habitats with a high conservation value. Among the candidate variables, the trophic state and connectivity emerged as the most promising surrogates for native species diversity. However, the predictive performance of the surrogate schemes was relatively weak, providing low support for use of environmental surrogacy in pond conservation planning. If the preservation of hydrophyte diversity is considered a legitimate conservation goal, easily accessible GIS data on connectivity may save costs and effort during the prioritization of hydrophyte hotspots. In the cases of other groups, detailed botanical surveys are necessary to make informed decisions on pond conservation. The occurrence and diversity of alien macrophytes was difficult to predict using the native species diversity or habitat characteristics of the ponds. A failure to identify surrogates for alien species and their strong potential impact on resident ecosystems implies that further monitoring of exotic plants in ponds is urgently needed, especially now, as the number of alien aquatic plant species steeply increases in Europe.

1. Introduction

Intensive research on ponds in the last few decades have recognized their critical importance for the maintenance of freshwater biodiversity (Biggs et al., 2005, 2017) and highlighted the role of ponds as key habitats that host many endangered aquatic plant species (Williams et al., 2004; Biggs et al., 2005; Davies et al., 2008a,b; Lukács et al., 2013). The proportion of ponds in the landscape is much higher than that of large waterbodies, and they comprise a major part of the continental waters in Europe (Oertli et al., 2009). For example, ponds represent almost 95% of all standing waters in Slovakia (Central Europe) (Fig. 1).

Conservation strategies for such abundant habitats call for the selection of prioritized sites that host many threatened species (Parviainen et al., 2009; Wilson et al., 2009). However, even for well-known taxa, detailed information on species distribution is typically

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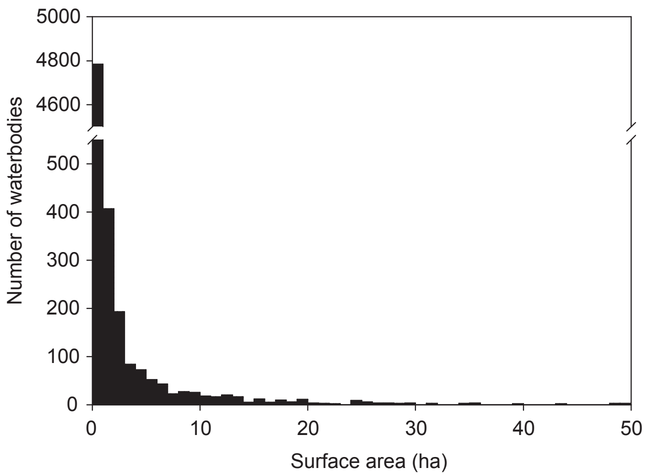

Fig. 1. Surface area distribution of standing waters in Slovakia according to a GIS-based inventory using a digital elevation model with a resolution of 10 m. Note that the x-axis displays only values < 50 ha (40 waterbodies; (0.7%) were excluded), and the y-axis breaks between 550 and 4500 for better scaling.

incomplete and often estimated indirectly using proxy approaches. The use of proxy variables as biodiversity indicators (Caro, 2010) may serve as a simpler and cheaper alternative for the estimation of diversity and setting conservation priorities compared to the collection of extensive data on regional biota. Environmental surrogates, i.e. environmental variables related to species distribution, are frequently proposed proxies for the prediction of species diversity and for prioritization in conservation planning (Sarkar et al., 2006; Caro, 2010). For example, Bacaro et al. (2011) found that using GIS-derived data on habitat productivity and heterogeneity, combined with basic topographic and geographic information may serve as useful surrogates to identify bird diversity hotspots. Similarly, Dalleau et al. (2010) showed how the high-resolution habitat maps may be used to cost-effectively design networks of marine protected areas for coral reefs. Nevertheless, the level of support for environmental surrogacy varies widely among published studies (Rodrigues and Brooks, 2007; Beier et al., 2015) which prevents unambiguous conclusions. Moreover, the efficiency of environmental surrogates has mostly been tested in terrestrial and marine environments (Sarkar et al., 2006; Rodrigues and Brooks, 2007; Beier et al. 2015). In freshwaters, attention has mainly been paid to stream ecosystems, while the surrogate-based conservation planning of pond or wetland habitats is underdeveloped (Nel et al., 2009). In the present paper, we specifically focus on pond ecosystems and test the usefulness of environmental surrogates for the conservation prioritization of macrophyte communities.

An efficient environmental surrogate scheme represents predictive model that should involve environmental variables that are tightly linked with the diversity of a target group. The diversity of aquatic macrophytes is shaped by a plethora of regional and local environmental cues that can be considered candidates to enter a surrogate scheme. Regional factors include a set of characteristics that influence the probability of a species reaching a given site and large-scale environmental conditions that affect the species pool in an entire region (e.g., catchment morphology, land use patterns). The diversity of macrophytes may increase with the abundance and proximity (connectivity) of other wetland habitats in the landscape (e.g., Biggs et al., 2005; Gledhill et al., 2008), but this is not necessarily the case (e.g., Møller and Rørdam, 1985; Edvardsen and Økland, 2006; Svitok et al., 2011), and the positive effect of connectivity may even be reversed by the presence of strong ecological interactions in highly connected waterbodies (Scheffer et al., 2006). The regional effects associated with intensive land use (e.g., crop lands, urban areas) are very typical for decreasing macrophyte diversity (Declerck et al., 2006; Akasaka et al., 2010). A high degree of variability also exists in the relationships between the local environment and the diversity of pond-dwelling macrophytes, but surface area, water chemistry and the hydrological regime are usually ranked among the most influential local factors (e.g., Biggs et al., 2005; Edvardsen and Økland, 2006; Della Bella et al., 2008; Hassall et al., 2011; Svitok et al., 2011, 2016). However, the relative importance of local and regional factors clearly depends on species life-history traits. For example, macrophytes from different emergent groups (i.e., group of species with shared life-history traits) are likely to respond to the variability of the pond environment in different ways, resulting in different diversity patterns (Edvardsen and Økland, 2006; Herault and Thoen, 2009; Akasaka et al., 2010; Pätzig et al., 2012). Surprisingly, most works considering plant biodiversity in ponds have been concerned with the overall richness and/or composition of macrophyte communities, ignoring life-history traits.

Given the extent of the variation in the diversity-environment relationships across pond systems, the geographical restriction of existing studies (mainly small-scale studies in Western Europe), the specific responses of emergent groups and the substantial amount of stochasticity (e.g., Capers et al., 2010), it is not surprising that making generalizations about these associations has proven to be difficult (cf. Belmaker and Jetz, 2011). Consequently, surrogate schemes are typical for a lack of transferability to other landscapes, ecosystems or environmental circumstances (Lindenmayer and Likens, 2011).

Therefore, an effective use of environmental surrogates assumes reliable predictability of biodiversity on new sites based on environmental variables in a given scheme. Predictive accuracy is, however, difficult to judge *a priori* because macrophyte diversity in freshwaters is highly variable (see above), potential surrogates may involve interactions of several environmental factors (Lacoul and Freedman, 2006; Capers et al., 2010) and also because ecologists rarely go beyond significance tests to assess whether models make accurate predictions with new data. Therefore, we combined the flexible regression tree approach, which can address nonlinear relationships and high-order interactions (De'ath, and Fabricius, 2000; Svitok et al., 2016), with predictive modelling, which can elucidate the practical relevance of environmental surrogates for conservation purposes (Houlahan et al., 2017).

To provide a robust test of environmental surrogacy, we performed a large-scale study of macrophyte communities in 92 ponds across the Pannonian and Carpathian biogeographical regions (Central Europe). Our aim was to identify and test the effectiveness of environmental surrogates that are readily available to establish conservation priorities for very abundant pond ecosystems. Specifically, we tested the performance of environmental surrogates to identify pond habitats with a high overall diversity and, in particular, a high diversity of threatened macrophytes. Moreover, we also focused on the surrogates for alien species richness, since an accurate estimation of habitat invasibility has become a priority for conservation efforts (Strayer, 2010; Havel et al., 2015).

We assumed that regional factors rank among the best environmental surrogates due to their large-scale nature. Since aquatic plants are traditionally thought to be limited by regional processes such as dispersal (cf. Capers et al., 2010), local factors were expected to be major surrogates for this emergent group. Finally, the distribution of alien species is frequently linked to the diversity of native communities (e.g., Levine and D'Antonio, 1999; Michelan et al., 2013) and disturbances that are generally considered to favour aquatic invasions (Strayer, 2010). Therefore, the richness of native communities and variables related to stress (e.g., proportion of urban areas in catchments, eutrophication) were expected to play prominent roles in the distribution of alien species.