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Macrophyte diversity of lakes in the Pannon Ecoregion (Hungary)

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ABSTRACT

We examined the distribution of submerged and emergent macrophyte species and the entire macrophyte community within and between five lake types (highland reservoirs, alkali lakes, large shallow lakes, small to medium sized shallow lakes, marshes) in the Pannon Ecoregion, Hungary. The lowest submerged, emergent and total species richness was found in alkali lakes. The highest submerged macrophyte richness was in small to medium sized lakes, while the highest emergent macrophyte species richness was in reservoirs, small to medium sized lakes, and marshes. The values of within-lake type beta diversity were generally lower than the values of alpha diversity, especially for submerged macrophytes, indicating between site homogeneity in species composition within the lake types. Emergent macrophyte communities contributed the most to within and between lake type diversity and total (gamma) diversity. Canonical correspondence analyses showed that the main environmental variables which influenced the distribution of submerged macrophytes were conductivity, Secchi transparency and water nitrogen contents. For emergent macrophytes conductivity, lake width, altitude and water depth proved to be the most influential variables. Our results contribute to the knowledge of large-scale distribution of macrophytes in the Pannon Ecoregion and to the identification of conservation value of lakes using macrophytes. The results support the importance of small lakes and artificial lakes in the conservation of macrophyte diversity compared to large and natural lakes in the Pannon Ecoregion.

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1. Introduction

Freshwater biodiversity is declining at an alarming rate. This rate is much greater than has been noted for even in the most affected terrestrial systems (Millennium Ecosystem Assessment, 2005). To set conservation priorities for these valued ecosystems, it is essential to understand spatial variation in the diversity of organism groups in an array of freshwater habitat types (Underwood et al., 2000; Anderson et al., 2005). Standing waters have a major contribution to the biodiversity conservation of freshwater ecosystems, and with their variety in forms and habitat characteristics they provide diverse habitats for freshwater organisms. Evaluation of the contribution of various types of ponds and lakes to regional biodiversity has only recently been started to come to the forefront of research for conservation purposes (Biggs et al., 2005; De Meester et al., 2005; Williams et al., 2004).

It has long been recognized that standing waters play an important role in the conservation of aquatic plants (Linton and Goulder, 2000; Oertli et al., 2002; Nicolet, 2001; Nicolet et al., 2004). Several studies examined the regional scale diversity of macrophytes, focusing mainly on the question how diversity is related to environmental variables. It has been suggested that macrophyte distribution and diversity is mainly related to water transparency, conductivity, lake area, altitude and human pressures (Vestergaard and Sand-Jensen, 2000; Akasaka et al., 2010; Hicks and Frost, 2011). It is much less known how the diversity of macrophyte species is distributed in the landscape among the standing water habitat types, and how these patterns in diversity are related to the various life-forms of species. For example, the foremost life-forms of macrophytes are submerged and emergent, which have a fundamental role in creating the main zones in shallow lakes (upper-littoral and lower-littoral). However, the distribution of their species diversity is virtually unknown within and between habitat types.

The vanishing of macrophyte-rich habitats, such as marshes and small ponds, due to desiccation and drainage is a serious

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Table 1
Overview of standing water types.

Code	Standing water type	Naturalness	Altitude (m)	Conductivity ($\mu S\,cm^{-1}$)	Water depth (m)	Secchi (m)	O_2 content ($mg\,l^{-1}$)	Lake zone	Number of lakes/sites
RES	Highland reservoirs	Artificial	237–554	166–1072	1.5–3	0.16–1.05	9.1–13.7	Pelagial	5/1
ALK	Alkali lakes	Natural	91–119	1849–6560	0.2–1	0.02–0.62	4.33–12.19	Littoral	11/1
BIG	Subbasins of Lake Balaton	Natural	98–118	774–1103	1.5–1.9	0.34–0.76	6.06–11.13	Pelagial	1/8
MED	Lowland small to medium size shallow lakes	Natural	83–213	200–1475	1.8–2.3	0.27–1.5	4.03–14.95	Pelagial	20/1
MARSH	Very shallow lakes	Natural	79–115	187–1184	0.05–1.2	0.05–1.2	0.25–6.4	Littoral	8/1

In the cells of the table minimum–maximum values are shown.

conservation problem. On the other hand, reservoirs built on streams for a variety of purposes (irrigation, flood control, fishing) may provide new artificial habitats for macrophytes (Céréghino et al., 2014), but the similarities and differences in their macrophyte diversity compared to that of the natural habitats should be directly quantified. Knowing the scale dependent relative contribution of alpha (mean local diversity) and beta (variation in species composition between sites or habitats) diversity to gamma diversity (total diversity within and between habitats) helps to define the relative value of different standing water habitat types in conserving macrophyte diversity and consequently, have the potential to help in optimizing conservation efforts at the regional scale. These issues can be effectively addressed using the method of diversity partitioning, which allows the quantification of the contributions of alpha and beta diversity to total diversity over a range of user-defined spatial scales. Thus, conservation biologists can set up priorities between sites and/or habitats across multiple scales (Gering et al., 2003).

The Pannon Ecoregion contains some unique standing water habitat types, which are rare (or missing) in other European regions. For example, many standing waters in the ecoregion have a peculiar astatic character (temporarily dried out) which is attributed to the arid continental climate (Szesztay, 1974; Horváth et al., 2013; Radulovič et al., 2011). The climatic, geomorphologic and hydrologic features of standing waters resulted in a variety of lake types with well-developed submerged and emergent macrophyte vegetation. The purpose of this study is to quantify the contribution of artificial and natural lake types to the biodiversity of macrophytes in the Pannon Ecoregion, Hungary. Specifically, we (i) examined the distribution of submerged and emergent species in five habitat types (reservoirs, RES; alkali lakes, ALK; large shallow lakes, BIG; small to medium sized shallow lakes, MED; marshes, MARSH) to compare similarities and differences in their species diversity and composition and to select the most valuable types for conservation planning, and (ii) studied the relationship between the distribution of species and the basic physico-chemical characteristics of the studied standing waters.

2. Methods

2.1. Study area

The Pannon Ecoregion is located in the Carpathian Basin, Central Europe (EEA, 2009). Ninety per cent of the Ecoregion area is in Hungary and 10% in other countries (Austria, Czech Republic, Serbia, Slovakia, Ukraine and Romania). Two-thirds of the ecoregion is in the lowlands (200 m), the remaining area belongs to mid-altitude regions (200–800 m). Only a small proportion of the area belongs to submontane region (>500 m). Formerly almost the entire lowland area formed the floodplain of large alluvial rivers coming into the Carpathian Basin. Large-scale river regulations altered the hydrological conditions of the landscape during the 19th century. These human perturbations led to the alteration or disappearance of natural habitats and to the development of new aquatic systems. As a consequence of the regulation of large potamal rivers certain types of standing waters were formed along the rivers (oxbow-lakes), while other types became scarce (alkali lakes) or disappeared (marshes).

Five habitat types were set up for Hungarian standing waters to obtain a useful landscape-level classification scheme based on the criteria outlined by Heino and Mykrä (2006), and using the top-down (system B) typology of the Water Framework Directive (Borics et al., 2014): reservoirs (RES); alkali lakes (ALK); lowland large shallow lakes (BIG), lowland small to medium sized shallow lakes (MED) and very shallow lakes (MARSH). Although the types have some overlapping physical characteristics, they can be easily distinguished based on some basic criteria (e.g. the status of naturalness, depth, see Table 1).

2.2. Site selection

Macrophyte data were collected during an ecoregion-wide survey of the biotic elements (ECOSURV Project 2005, http://www.eu-wfd.info/ecosurv). Aquatic macrophytes were studied in 52 standing water bodies all over Hungary (Fig. 1) in 2005 from the end of May to end of July, which is an appropriate time for field sampling. Sites were selected to represent the approximate ratio of the different lake types in the region. In case of large lakes (BIG), we used macrophyte data originated from the different basins (separated by an average distance of 12 km) of Lake Balaton, which is the largest shallow lake in Central Europe. We emphasize that the basins have differences in morphology, trophic state (Istvánovics et al., 2007) and are also separately handled in water management (VKKI, 2010a).

2.3. Macrophyte sampling

Macroalgae (*Chara* and *Cladophora* species) and vascular plants (submerged, floating, emergent and shoreline plants) were collected in transects. Prior to the establishment of transects the ratio of macrophyte coverage and the main types of macrophyte stands were checked using aerial photos. Five transects (100 m long and 3 m wide) were located from the open water to the outer edge of emergent vegetation, perpendicular to the shoreline following the protocol of Schaumburg et al. (2007). Emergent species spread beyond the shoreline to a maximum distance of 1–2 m (spray zone). In shallow lakes and marshes, the bottom-living plants were sampled by rakes, whereas in deeper waters a grapnel with a 10 m long rope was used. The field protocol with a five-level descriptor scale was used during field survey (Stelzer et al., 2005). Vascular plants were identified to species level using Király's (2009) handbook,

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