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Macrophyte assessment in European lakes: Diverse approaches but convergent views of 'good' ecological status

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ABSTRACT

The European Water Framework Directive has been adopted by Member States to assess and manage the ecological integrity of surface waters. Specific challenges include harmonizing diverse assessment systems across Europe, linking ecological assessment to restoration measures and reaching a common view on 'good' ecological status.

In this study, nine national macrophyte-based approaches for assessing ecological status were compared and harmonized, using a large dataset of 539 European lakes. A macrophyte common metric, representing the average standardized view of each lake by all countries, was used to compare national methods. This was also shown to reflect the total phosphorus ($r^2 = 0.32$), total nitrogen ($r^2 = 0.22$) as well as chlorophyll-*a* ($r^2 = 0.35$–0.38) gradients, providing a link between ecological data, stressors and management decisions. Despite differing assessment approaches and initial differences in classification, a consensus was reached on how type-specific macrophyte assemblages change across the ecological status gradient and where ecological status boundaries should lie.

A marked decline in submerged vegetation, especially Charophyta (characterizing 'good' status), and an increase in abundance of free-floating plants (characterizing 'less than good' status) were the most significant changes along the ecological status gradient. Macrophyte communities of 'good' status lakes were diverse with many charophytes and several *Potamogeton* species. A large number of taxa occurred across the entire gradient, but only a minority dominated at 'less than good' status, including filamentous algae, lemnids, nymphaeids, and several elodeids (e.g., *Zannichellia palustris* and *Elodea nuttallii*). Our findings establish a 'guiding image' of the macrophyte community at 'good' ecological status in hard-water lakes of the Central-Baltic region of Europe.

1. Introduction

Macrophytes are important components of lake ecosystems, contributing to primary productivity, sediment accumulation and stabilization, storage and cycling of nutrients, as well as providing complex habitat and food for (semi-)aquatic biota from macroinvertebrates to mammals (Jeppesen et al., 2012). In shallow lakes, they are particularly important as they can contribute to a clear-water state through various self-enhancing feedback mechanisms (Scheffer and Carpenter, 2003). Macrophyte communities also contribute to the provision of ecosystem services to society, including sustainable production of food, recreational opportunities, and water purification (Engelhardt and Ritchie, 2001; Hilt et al., 2017).

In most European lakes the composition and abundance of macrophytes has changed because of various human pressures (Körner, 2002; Sand-Jensen et al., 2000). Macrophytes are sensitive to eutrophication (Madgwick et al., 2011; Søndergaard et al., 2010), acidification (Arts, 2002, Brouwer et al., 2002), water level fluctuations (Mjelde et al.,

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Table 1
Macrophyte methods for lake ecological status assessment included in the analysis; macrophyte groups: SUBM – submerged rooted and non-rooted, FLOAT – floating-leaved rooted and free floating; HELO – helophytes, FILA – filamentous algae (large), MOSS – mosses, CYAN – cyanobacterial films.

Member State	Method and reference	Sampling procedure	Macrophyte groups included	Abundance scale
Belgium Flanders (BE-FL)	Flemish macrophyte assessment system (Schneiders et al., 2004; Leyssen et al., 2005)	Point observations in all homogeneous parts up to 2 or 4 m depth	SUBM, FLOAT, HELO, FILA, MOSS, CYAN	5-point scale for individual taxa and 4-point scale for total abundance
Denmark (DK)	Danish Lake Macrophytes Index (DLMI, Søndergaard et al. 2013)	Transects	SUBM, FLOAT, (FILA)*, (MOSS)	6-point scale for each observation point, translated into % coverage
Estonia (EE)	Estonian macrophyte assessment system (Portielje et al., 2014)	Transects for larger lakes, total mapping for smaller	SUBM, FLOAT, (HELO), FILA, MOSS	Separate 5-point scales for SUBM, FLOAT and HELO
Germany (DE)	German Assessment System for Macrophytes & Phytobenthos (Reference Index, Schaumburg et al., 2004)	Transects of ca. 20 m width	SUBM, FLOAT, MOSS	5-point scale for taxa in each depth zone
Latvia (LV)	Latvian macrophyte assessment method (Portielje et al., 2014)	Transects	SUBM, FLOAT, HELO, FILA, MOSS	5- or 7-point scale
Lithuania (LT)	Lithuanian macrophyte assessment method (Portielje et al. 2014)	Transects	SUBM, FLOAT, (HELO), (FILA), MOSS	5-point semi quantitative scale
Netherlands (NL)	WFD-metrics for natural water types (Coops et al., 2007)	Sampling points of a size of 200 × 200 m for larger lakes and transects for smaller lakes	SUBM, FLOAT, HELO, FILA, MOSS	9-point scale for individual taxa and percentage cover for total abundance
Poland (PL)	Ecological Status Macrophyte Index (ESMI, Ciecierska and Kolada, 2014)	Transects of ca. 30 m width	SUBM, FLOAT, HELO, MOSS	7-point scale for taxa and percentage cover for total abundance
United Kingdom (UK)	LEAFPACS lakes macrophyte classification tool (Willby et al., 2012)	Transects of ca. 100 m width	SUBM, FLOAT, FILA, MOSS, CYAN	Percentage cover of each taxa

2013; Wantzen et al., 2008), shoreline modifications (Ostendorp et al., 2004), recreation (Asplund and Cook, 1997; Mosisch and Arthington, 2004), navigation (Willby et al., 2001), fish stocking (Williams et al., 2002), and biological invasions (Strayer, 2010).

Many European countries have therefore included macrophytes in their ecological assessment tool-kit, for example, Austria (Pall and Moser, 2009), Denmark (Søndergaard et al., 2010), Germany (Schaumburg et al., 2004), Ireland (Free et al., 2006), Poland (Ciecierska and Kolada, 2014), and UK (Willby et al., 2012). Due to their sedentary nature and relatively slow growth, macrophytes can serve as long-term indicators with high spatial resolution, useful for detecting nutrient enrichment and other impacts occurring at the land–water ecotone (Melzer, 1999; Pall and Moser, 2009).

To ensure comparability of ecological assessment and promote shared levels of ambition among EU member states, the Water Framework Directive (EC, 2000) stipulates that assessment systems are compared and that status boundaries should be adjusted where necessary (Birk et al., 2013). This task of intercalibration has proved challenging, mainly due to intrinsic biogeographical differences between member states and the diversity of sampling, analysis and evaluation approaches they use (Penning et al., 2008a; Poikane et al. 2014b, 2015). In lowland Europe especially, intercalibration has been hindered by the lack of near-natural reference sites, short pressure gradients, multiple pressures acting on the same sites, confounding factors (e.g. suspended solids and water colour) and different monitoring practices and assessment philosophies (Tóth et al., 2008). In order to overcome these difficulties, innovative approaches have been developed (EC, 2011; Poikane et al., 2014b). A benchmarking procedure allows any typological or biogeographical differences between countries to be removed by normalization (Birk et al., 2013; Poikane et al., 2015). Intercalibration can be carried out by a direct comparison of commonly assessed sites or indirectly, using a common biological or pressure index (Kelly et al., 2014; Poikane et al., 2016a, 2017). The concept of a 'harmonisation band' has been introduced to unify both approaches and to convey the magnitude and direction of deviation of national methods from the global average view of ecological status (Birk et al., 2013).

However, ecological assessment is not a panacea that will single-handedly ensure 'good' ecological status of European waters. The next steps toward this challenging goal include diagnosing causes (e.g., nutrient enrichment), defining management targets (e.g., nutrient concentrations) and suggesting restoration measures to remedy the situation. Pressure-response relationships between stressors and biota are one means towards these ends (Karr, 1999; Hering et al., 2010). However, these relationships have not been tested or documented for one-third of the methods proposed so far for the Directive (Birk et al., 2012). Consequently, the necessary links between ecological status and management decisions are obscure or even absent in many river basin management plans, creating one of the most important gaps in the WFD implementation (Hering et al., 2010, 2015).

Last but not least, it is necessary to communicate about the health of lake ecosystems to the public and decision makers (Karr, 1999; Kelly, 2012). Great efforts have been made in ecological assessment to reduce biological communities to metrics and indices. Additional efforts have been made to make these numbers comparable among member states (Birk et al., 2013). Now, it is essential to transform these numbers back into a narrative on healthy aquatic ecosystems and communicate why this is important, not just to ecologists, but also to water managers and citizens (Willby, 2011; Poikane et al., 2016b). A description of biological communities at different ecological status classes (Birk and Willby, 2010) along with a common understanding of community composition at 'good' status ('guiding image'; Palmer et al., 2005) can serve as a first step towards this goal.

In this study, we seek to provide a simple overview of the process of intercalibration performed on assessments of lake ecological status based on macrophytes and then demonstrate that the result has ecological relevance for lake management in Europe.