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An assessment of the ecological potential of Central and Western European reservoirs based on fish communities

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ABSTRACT

In this study we developed a novel methodology based on fish communities to assess the ecological potential of central European reservoirs. Using the hindcasting approach, our index predicts values that could be observed in the absence of pressures for each reservoir depending on their environmental characteristics. Fish data were collected from 144 French and Czech reservoirs between 2005 and 2013 by standardized benthic gillnet sampling and transformed to functional and taxonomical metrics. After all validation by multiple testing of models redundancy and pressure-response, the final index was composed of three metrics: total biomass of fish, abundance of invertivores/piscivores, and abundance of planktivorous fish. The index accurately identifies reservoirs that are lightly, moderately and heavily affected by eutrophication. In addition to French and Czech reservoirs, this index could be a useful tool for countries with few reservoirs and the basis for further collaborative studies.

1. Introduction

Reservoirs are artificial water bodies, classified as heavily modified water bodies (HMWB) under the Water Framework Directive (WFD) and in many areas they replace natural lakes. Similarly to lakes, HMWB are subject to anthropogenic stressors. Therefore it is necessary to evaluate how a reservoir ecosystem changes, and how serious or reversible these changes are (Scheffer and Carpenter, 2003). To protect and manage these systems, the WFD requires European Union member states to assess the ecological potential of their HMWB using a holistic approach (European Commission, 2000). The ecological status is defined according to the biological, chemical and physical characteristics of the water bodies and their variation from reference cases. Research efforts over the last decade were mostly dedicated to developing methodologies to assess the ecological status of natural water bodies (e.g. WISER project http://www.wiser.eu or FAME project http://fame.boku.ac.at) but little effort addressed other categories of water bodies such as HMWB, particularly reservoirs. The few assessment systems developed for reservoirs have so far not been applied to an area larger than a single country (Jennings et al., 1995; Navarro et al., 2009; Han et al., 2014). The evaluation of ecological quality is challenging because reservoirs are complex systems that represent a transitional environment between lakes and rivers (Wetzel, 2001; Irz et al., 2002; Straškraba, 2005) and usually do not have an undisturbed reference state.

The variability of environmental conditions and diverse human uses create complex reservoirs and affect the organisms that inhabit these systems (Straškraba, 2005). The morphology of a reservoir depends on that of the original river valley prior to damming and the depth of a reservoir usually increases from the tributary to the dam. Big dams block the movements of fish, create unnatural flow regimes and alter energy transport between aquatic and terrestrial environments. Three distinct morphological zones occur in reservoirs: riverine, transition and lacustrine zone (Wetzel, 2001). Each zone is inhabited by specific biota that contribute to the complexity of the ecosystem. In addition the WFD states that management of reservoirs for human uses is a component of the functioning of the system and cannot be considered as a stressor (European Commission, 2000). Due to all these characteristics, reservoirs have functions that are not comparable to natural lakes (Launois et al., 2011b) and thus merit specific scientific focus.

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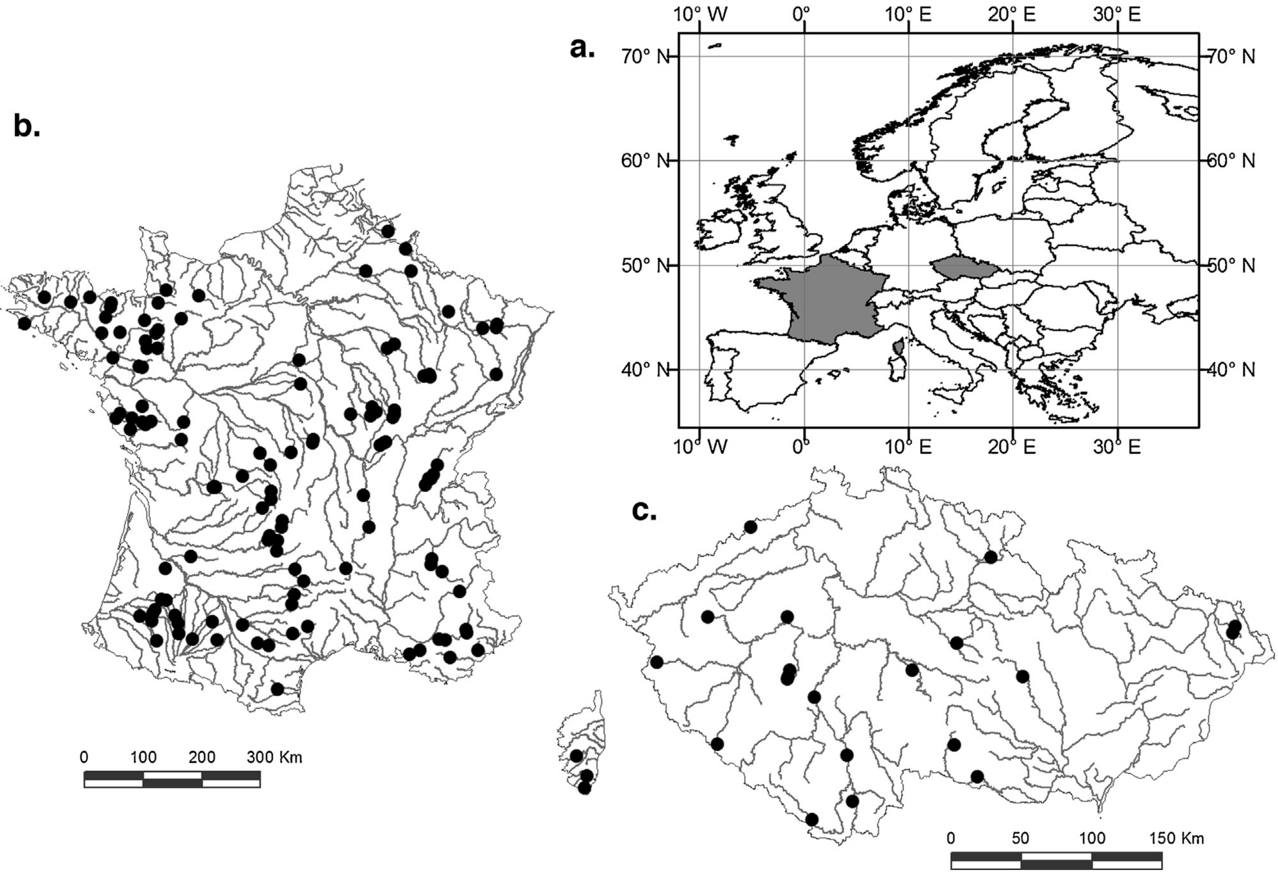

Fig. 1. Map of Europe indicating the position of France and the Czech Republic (a) and the geographic distribution of the reservoirs included in the dataset in France (b) and in the Czech Republic (c), for details see Table A1 in the Supporting Information.

The WFD emphasizes the central role of four biological groups to assess the health of aquatic ecosystems: flora, benthic invertebrates, fish fauna, and phytoplankton. While fish in general are sensitive to a variety of natural and disturbance factors (Karr, 1981; Karr et al., 1986), each species can also have its own impact on the biological processes in aquatic ecosystems (Carpenter et al., 1985). The lifespan of fish is long enough to integrate long-term changes and they are also sensitive to acute harmful events in ecosystems. Through their mobility and presence at different trophic levels, fish provide an integrative view of the ecosystem (Lindeman, 1942; Karr et al., 1986). The species composition of fish communities may differ between locations but functional composition offers a way to easily compare communities on a wider scale (Logez et al., 2013). Finally, fish are a highly visible component of the aquatic community to the public and the combination of commercial and recreational fisheries suggests that fish are more suitable than any other biota to guide management strategies to improve ecological quality.

The aim of this study was to develop a fish index compatible with WFD requirements that could be applied in Central and Western Europe by compiling standardized fish data (CEN, 2005) and environmental and pressure data from French and Czech reservoirs. A hindcasting approach that enables the prediction of expected metric values in the absence of pressure data for each reservoir based on their environmental characteristics was used (Baker et al., 2005; Kilgour and Stanfield, 2006). Once the environmental variability of metrics was controlled, the metrics most sensitive to human pressures were selected and combined into a final index that can be applied to identify restoration priorities and improve ecosystem health (Pont et al., 2006, 2007; Argillier et al., 2013).

2. Material and methods

2.1. Dataset

The database contains information from 124 French and 20 Czech fish sampling campaigns in different reservoirs (Fig. 1, Table A1 in Supporting Information) covering 6 ecoregions (Illies, 1978). In reservoirs with multiple years of sampling, only the most recent data was used.

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2.2. Fish sampling

The fish communities were sampled by benthic gillnets from 2005 to 2013 during the period between July and the middle of October. Depth stratified sampling, together with total effort derived from reservoir area, and maximum depth were applied as recommended by CEN (2005). For instance, in reservoir with a maximum depth of 4 m and area 0.4 km^2, the number of nets used was 7, whereas in reservoir with a maximum depth 30 m and area 1.4 km^2 the maximum number was 80. Benthic gillnets, 30 m in length, 1.5 m in height, and composed of 12 panels with mesh sizes ranging from 5 to 55 mm knot-to-knot were used. The gillnets were set before sunset and lifted after sunrise to cover maximal peaks of fish activity (Prchalová et al., 2010). All age categories were taken into account during analyses, including young-of-the-year. Fish were identified to species level, measured to total length and weighed. The abundance and biomass were expressed as catch (number of