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Research paper

The Benthic Invertebrates Floodplain Index – Extending the assessment approach

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ABSTRACT

Floodplains are highly diverse landscape elements within river systems and among the most endangered ecosystems worldwide. In this paper we complement indices developed to assess the ecological status of floodplain systems, compliant with the EU Water Framework Directive, to an overall "Benthic Invertebrate Floodplain Index" (BIFI). With the addition of taxa (mainly oligochaetes, chironomidae and amphipoda) to the floodplain index (FI), caddisfly (CHI), and dragon fly (OHI) indices a new extended BIFI can be calculated. We provide values for the calculation of the index derived from a comprehensive dataset of Austrian floodplain waters complemented by literature data. Values are given for those taxonomic groups which are abundant in the Austrian Danube and determinable in reasonable time. The new index was compared to published floodplain indices and tested with an independent data set at two floodplain segments along the Austrian Danube. The newly classified benthic invertebrates (NCBI) showed a good performance in comparison to the so far published indices and extend these to a better coverage of dynamic water bodies. Further the inclusion of abundant and species rich taxa improves the robustness of calculated values already with a low sampling effort. Altogether it is a promising tool for the integrated assessment of the ecological status of river-floodplain systems according to the EU Water Framework Directive.

1. Introduction

The EU Water Framework-Directive (WFD, 2000) focuses on the conservation and restoration of the "good ecological status" of aquatic ecosystems in relation to "ecological reference conditions". It was established to assure an integrated water policy within the European Union that acknowledges the sensitivity of these systems in order to provide a legal framework for sustainable management. Since its implementation the WFD is greatly increasing knowledge on the ecology of European surface waters, but has also received major criticism, from politicians, water managers and scientists especially for its implementation in practice (e.g. Dufour and Piégay, 2009; Hering et al., 2010; Moss, 2008). A critical review (Hering et al., 2010) showed that the performance of ecological assessment varies between regional, national and European scales, across seasons and ecosystems types. They conclude that especially rivers are very diverse systems under complex multiple stressor situations and assessment systems are often less predictable compared to those developed for lakes and coastal/transitional waters. The WFD stresses the importance of the transition zones between the aquatic and terrestrial ecosystems, floodplains and wetlands, for riverine systems. For maintaining as well as restoring these important ecosystems long term measures should be considered (CIS, WFD, 2003). Anyway, WFD does not clearly state the extent to which the protection as well as the enlargement (i.e. gaining former floodplain area and improving the connectivity, Buijse et al., 2002) of those wetlands should be used in order to achieve the environmental objectives (Meyerhoff and Dehnhardt, 2007).

Birk et al. (2012) investigated over 300 European assessment tools for water bodies. Implemented methods cover rivers, lakes, coastal waters, and transitional zones (transition between sea and freshwater). Although different tools for rivers might partially integrate floodplains and wetlands into the assessment, no methods are implemented specifically for floodplains. However, these habitats show a wide range of hydrological conditions from lotic to lentic and from permanent to temporary conditions due to changing riverine water levels and therefore changing connectivity patterns (Amoros et al., 1987), which are of great importance for river-floodplain systems. This variability in connectivity allows the development of different habitat types typical for large floodplain areas ranging from highly connected water bodies (eupotamon) to highly terrestrialized ones (paleopotamon) in the

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Table 1
Description of the five habitat types of the floodplain index (FI, Chovanec et al., 2005; Ward and Stanford, 1995).

Habitat type	Characterization
H1	Hydrologically dynamic water bodies, full-width surface connection with the main channel at both ends at mean water discharge and not fragmented by impoundments (e.g. small weirs); generally high water velocities; no macrophyte communities in the open water; open banks or *Phalaridetum* stands in the littoral area; sand and gravel substrate are dominating, occurrence of sand and gravel bars.
H2	Water bodies which lack unidirectional current; full-width surface connection which also lacks fragmentation by impoundments (e.g. small weirs) only at the downstream end at mean water level; only few macrophytes (e.g. *Phalaridetum*); high proportion of sand and gravel substrates, occurrence of sand and gravel bars.
H3	No connectivity with the main channel at mean water level; terrestrialisation processes; macrophyte cover of open water areas does not exceed 20% of open water area; dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo-Nupharetum, Magnocaricetum*; increased degree of sedimentation.
H4	No connectivity with the main channel at mean water level; terrestrialisation processes; macrophyte cover of open water areas exceeds 20% of open water area; dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo- Nupharetum, Magnocaricetum*; high degree of sedimentation.
H5	Temporary pools; sedimentation high; most years with at least one dried-up period (mainly summer-autumn); dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Magnocaricetum*; terrestrial vegetation.

lateral dimension (Ward and Stanford, 1995). These wetlands with their inherent biodiversity are among the most endangered ecosystems worldwide (Tockner et al., 2010). Up to 90% of the floodplain systems in Europe and North America are strongly impaired by human activity or already functionally extinct (Tockner and Stanford, 2002; Tockner et al., 2009). For example in the Danube River 68% of floodplain areas have been lost (Hein et al., 2016) pointing to the importance of increased conservation and restoration effort.

The current absence of defined assessment procedures for floodplains in the WFD stresses the need to establish a sound assessment method for floodplains. Any assessment needs to consider that floodplain reaches cannot be represented by simple main channel assessments, moreover, based on historic analyses the river channel is an integral part of a floodplain reach. De Leeuw et al. (2007) described two options for a combined assessment of main river and floodplain system, the first considers main channel and floodplain habitats as an integrated system for a combined assessment; the second is to assess the ecological status of the main channel and the floodplain water bodies independently in parallel.

Although so far no assessment procedure has been established within the WFD, there are some tools available to assess floodplain waters, which would fulfill the requirements of the EU WFD. The first ones were developed as the „Odonate habitat index“ (OHI) based on dragonfly communities (Chovanec and Waringer, 2001; Chovanec et al., 2004) and the „Caddisfly habitat index“ (CHI) for the assessment based on Trichoptera (Waringer and Graf, 2002). The „Floodplain Index“ (FI) was then proposed as a multi-species approach based on a comprehensive set of five aquatic indicator groups: molluscs, caddisflies, dragonflies, amphibians, and fish (Chovanec et al., 2005; Waringer et al., 2005). Recently species from additional invertebrate taxa were added (Šporka et al., 2016). The index is an autecology-based approach using species-specific habitat values, expressing the habitat preferences in a gradient of lateral hydrological connectivity, and species-specific indication weights, distinguishing eurytopic from stenotopic organisms. The ecological status is assessed based on a comparison of the status quo, calculated via the index, and river-type-specific reference conditions.

The aim of the present paper is to complement the so far developed indices and classified taxa of benthic invertebrates (see Chovanec and Waringer, 2001; Graf et al., 2013; Graf and Chovanec, 2016; Waringer et al., 2005; http://www.freshwaterecology.info/) to the „Benthic Invertebrate Floodplain index“ (BIFI). Together with the assessment methods for macroinvertebrates focusing on the main channel (e.g. Ofenböck et al., 2004; Hering et al., 2002) a status assessment of river-floodplain stretches was developed and tested. Classifications are derived from data collected in floodplains of the River Danube east of Vienna, Austria – the Nationalpark Donau-Auen – and were complemented with literature data on the autecology of the species with specific reference on their lateral and longitudinal zonation (e.g. Schmidt-Kloiber et al., 2006; Schmidt-Kloiber and Hering, 2015; Skern et al., 2010). The new index was compared with published indices in a floodplain system close to Vienna, the Lower Lobau, and tested in two other floodplain segments, Orth and Regelsbrunn, in the same river reach.

2. Material and methods

2.1. Proposed assessment procedure of the BIFI

We propose an assessment procedure for the BIFI analogous to the already published indices, the OHI (Chovanec and Waringer, 2001), FI (Chovanec et al., 2005), and the CHI (Waringer and Graf, 2002). Thus, only a brief summary is given here:

Within a system of five habitat types ranging from dynamic water bodies of the Eu- and Parapotamal (types H1, H2 according to Amoros et al. (1987), respectively) to isolated astatic waterbodies (H5) of a theoretic floodplain system, 10 valency points (VP) are allocated to each species according to the respective habitat preferences. For the so far classified taxonomic groups this allocation was done by expert judgment, for the newly classified species within this study the allocation is based on the analysis of empirical data and literature records. Habitat types can be distinguished based on hydrological connectivity with the main channel, permanence of water, and macrophyte cover (Table 1). Based on these valency points (VP) per habitat type (H1 to H5), the species-specific habitat preference (habitat value, HV) can be calculated for each individual species using the following equation:

$$HV = (1*H1 + 2*H2 + 3*H3 + 4*H4 + 5*H5)/10 \quad (1)$$

Further an indication weight (IW) is allocated to each species. It is a value ranging from 1 for eurytopic species to 5 for stenotopic species and gives weight to species with a higher habitat specifity. Species with an indication weight of at least 3 are defined as sensitive species.

The calculation of the index (FI) is based on samples (presence/absence data) of the respective species collected in different water bodies of a floodplain system aiming to cover the whole range of existing habitat types. The FI is then calculated for each water body based on the species-specific habitat preference values (HV) and the indication weights (IW) of the present species using the following formula,

$$FI = \Sigma(HV*IW)/\Sigma IW \quad (2)$$

Based on the calculated FI values, habitat types can be allocated to each sampled water body following Table 2.

In concordance with the WFD, the ecological integrity of a river can then be determined in comparison to the natural or near-natural reference conditions for the specific river type. These reference conditions can either be determined by expert judgement, other still existing reference sites or by assessment of the historic situation prior large-