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www.freshwaterecology.info – An online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences☆

Astrid Schmidt-Kloiber[a,*], Daniel Hering[b]

[a] University of Natural Resources and Life Sciences, Institute of Hydrobiology and Aquatic Ecosystem Management, Max Emanuel-Straße 17, 1180 Vienna, Austria
[b] University of Duisburg-Essen, Faculty of Biology, Department of Aquatic Ecology, Universitätsstraße 5, 45141 Essen, Germany

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ABSTRACT

Species' ecological preferences are progressively important for understanding distribution patterns, for conserving biodiversity or for assessing and evaluating the status of freshwater ecosystems. Comprehensive databases compiling species traits are already established in the terrestrial realm, but widely missing in freshwater science. We established a database for European taxa of five aquatic organism groups by compiling information on taxonomy, ecology and distribution based on extensive literature surveys, which were performed by experts for the targeted organism groups. The database includes fishes (654 taxa/21 ecological preferences), macro-invertebrates (8586/40), macrophytes (1083/5), diatoms (8868/36) and phytoplankton (1976/4). It is available online with various options and tools for finding information and has currently over 800 users. The reviewed literature as well as examples given in this paper, highlight the importance of the general availability of knowledge on ecological preferences for various aspects in ecological assessment. Freshwaterecology.info is considered a service for basic research, applied scientists, water managers or other stakeholders. It serves as base for bioassessment and monitoring.

1. Introduction

European rivers, lakes, ponds and wetlands are inhabited by a multitude of organisms: Balian et al. (2008) counted more than 30,000 described animal species for the Palaearctic region, of which Europe is a part. The Fauna Europaea lists 146,288 accepted species and subspecies, but includes the terrestrial fauna (de Jong et al., 2014). There are also at least 500 strictly aquatic vascular plant species (Chambers et al., 2008). Much freshwater biodiversity is represented by algae, unicellular eukaryotes (including diatoms), aquatic fungi and bacteria, for most of which only vague species numbers can be given. These organisms are an important part of Europe's natural heritage and the basis for the functioning of freshwater ecosystems.

Related to the area covered, freshwater ecosystems are much more species rich than terrestrial or marine ecosystems (Dudgeon et al., 2006). At the same time, freshwater biodiversity is declining faster than terrestrial or marine biodiversity (Dudgeon et al., 2006; Loh and Wackernagel, 2004; Millennium Ecosystem Assessment, 2005; Palmer et al., 2010) due to a multitude of stressors affecting inland waters, including overexploitation, habitat destruction, pollution by nutrients, organic and toxic substances and the invasion of non-native species and climate change. The preservation of freshwater ecosystems and their biodiversity is therefore a challenge of the coming decades.

In Europe, environmental legislation aiming to protect and restore freshwater ecosystems and their biodiversity mainly originated in the 20th century but has largely been put into practise in recent years. Both the Habitats Directive (HD; Council Directive 92/43/EEC) and the Water Framework Directive (WFD; Directive 2000/60/EC) have a strong focus on ecology and biodiversity. With the WFD aquatic organisms have been placed into a unique position, as the composition of freshwater biota defines the status of surface water bodies, and thus determines the needs for restoration and associated investments. This approach includes classical

☆ *Data accessibility*: All data referred to in this manuscript are available at www.freshwaterecology.info.

* Corresponding author. Tel.: +43 1 47654 5225; fax: +43 1 47654 5217.
E-mail addresses: astrid.schmidt-kloiber@boku.ac.at (A. Schmidt-Kloiber), daniel.hering@uni-due.de (D. Hering).

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bioindication, i.e., the detection of eutrophication, organic pollution or acidification by indicator organisms, but is also a general valuation of biodiversity per se, as undisturbed biotic communities are always used as a reference for classifying a water body's status. Thus, the WFD can be seen as the main driver for the development of ecological assessment systems at the European scale in recent years and therefore also fostered the engagement with ecological classifications.

When using the bioindication potential of freshwater organisms generally two different approaches have been used, which can be exemplified for benthic invertebrates: "biological traits" and "ecological preferences". Traits seek to functionally classify taxa grouped by comparable biological profiles; they are a powerful approach in understanding benthic community functioning and subsequently can be used in ecological freshwater assessment. Based on the assumption that traits are mainly coupled with phylogenetic units, e.g., all species of one genus or family have similar life cycles, reproduction strategies, etc., the databases available so far mainly classify taxa on levels higher than species by coding "modalities" (in the sense of properties) for different traits (e.g., for Europe: Dolédec et al., 2000, 1999; Statzner et al., 2001a,b; Tachet et al., 2010; Usseglio-Polatera et al., 2000a,b; for North-America: e.g., Merritt et al., 2002; Poff et al., 2006; Vieira et al., 2006). A different approach regarding the ecological preferences of species was originally based on the detection of organic pollution in freshwaters, e.g., saprobic valences of species indicating their tolerance to oxygen depletion (Sladecek, 1973; Zelinka and Marvan, 1961). This concept has been extended to several other ecological characteristics such as feeding preferences, stream zonation preferences, habitat preferences or current preferences. This method includes the ecological variability among and within genera and therefore considers species. The first compilations of species' preferences regarding different ecological aspects were published by Moog (2002, 1995) for Austria and by Schmedtje and Colling (1996) for Germany, later an extensive publication for the Slovakian Fauna was released (Sporka, 2003). The ecological preferences approach uses different types of coding systems, including the assignment of indicator values (for details see Section 2.2 below).

Both approaches require profound knowledge of the ecology of aquatic species. Such information was already partly available with the implementation of the WFD in the year 2000. However, data were scattered, often inaccessible and mainly restricted to individual countries. Information differed much in quality and precision between regions, organism groups and taxonomic resolution. An overview of coarse level distribution patterns including some ecological preferences of the European freshwater fauna was already provided by Illies (1967). Since then, much additional knowledge has been generated or compiled. In terms of distribution patterns, the Fauna Europaea was a milestone, providing checklists broken down by countries of many animal groups, including the major freshwater inhabiting taxa (de Jong, 2013; de Jong et al., 2014). A similarly comprehensive overview for freshwater plants is still not available. For other freshwater organism groups, knowledge on ecological preferences remained less complete, despite the development of several assessment indices and associated species' classifications, e.g., for diatoms (Almeida et al., 2014; Besse-Lototskaya et al., 2011; Lecointe et al., 2003), and fish (Pont et al., 2007, 2006; Schmutz et al., 2007a,b).

Compared to freshwaters, in the terrestrial realm, recently several attempts were undertaken to compile ecological knowledge on certain organism groups into databases, such as the LEDA life-history database of the northwest European flora (Kleyer et al., 2008; Knevel et al., 2003), the TRY database for global plant traits (Kattge et al., 2011) or the PanTHERIA database for recently extinct mammals (Jones et al., 2009).

For European freshwater organisms, the freshwaterecology.info database aims to bring together different data sources into a comprehensive overview of distribution patterns and ecological preferences. Further, it targets to make this information available for general use via an online platform. Originally designed for retaining data on macro-invertebrates in selected European countries (Schmidt-Kloiber et al., 2006), the database has been incrementally extended, now covering Europe as a whole as well as several organism groups (phytoplankton, diatoms, macrophytes, macro-invertebrates and fish).

This article summarises the contents of the database (as of 01/09/2014), describes its use by providing examples for its application and gives an outlook regarding future challenges.

2. Data compilation and data treatment

2.1. Data compilation

The data compilation of freshwaterecology.info included – though conducted in successive steps – fish, macro-invertebrates, macrophytes, diatoms and phytoplankton. Data were gathered and processed in the framework of EU-funded projects, which were partly overlapping and partly consecutive. The starting point for each group was always the compilation of a species list to serve as taxonomic backbone of the database. For each organism group, European experts collectively agreed on firstly such a list and secondly on ecological information to be included into the data compilation. Parameter selection was based on the relevance for bioindication, regardless of information availability.

Many authors distinguish between biological (e.g., life history) and ecological traits (e.g., habitat requirements) (e.g., Devin and Beisel, 2007; Usseglio-Polatera et al., 2000a). Others disagree in considering an ecological preference to be a trait, but define it as the result of how a trait has interacted with environmental conditions (Verberk et al., 2013). However defined, the collection of information for the freshwaterecology.info database involved biological traits, ecological preferences and classical indicator values (as e.g., saprobic indicators), all further referred to as "ecological parameters" in this article.

The ecological parameters (Table 1) were classified into the following groups: (a) distribution (e.g., occurrences per country, per ecoregion or per catchment), (b) spatial preferences (e.g., stream zonation or altitudinal preferences), (c) habitat preferences (e.g., hydrologic, temperature or salinity preferences), (d) pollution, trophy and saprobity (e.g., different saprobic and trophic indices) and (e) life history (e.g., life span, fecundity, feeding types). For some organism groups species affected by climate change were listed in addition.

By default, the ecological information was assigned to species (or even lower taxonomical levels). Higher systematic units (e.g., genus) were only classified if all the species within the genus had similar ecological assignments.

2.1.1. Fish

Within the EU funded projects FAME and EFI+ a list of European fish species was compiled (EFI+ Consortium, 2009; Fame Consortium, 2004; Pont et al., 2006). Experts from 14 European countries classified these species into guilds, based on existing literature and their expert knowledge. This ecological database was amended with available information from other literature sources afterwards.

2.1.2. Macro-invertebrates

The macro-invertebrate taxalist was compiled within the projects AQEM (Hering et al., 2004) and STAR (Furse et al., 2006) and data on ecological preferences readily available from Moog