Introduction to the series

Freshwater species live in a large variety of habitats and differ greatly in their ecological preferences. Through evolutionary processes over millions of years, aquatic organisms, in particular aquatic insects, have diversified into a highly speciose fauna, with a wide variety of ecologies. Species may prefer lentic or lotic ecosystems, different river zones (from springs to large rivers) or varied microhabitats (e.g., stones, sand or macrophytes). Many species have specialized diets and have developed distinct feedings strategies, ranging from algal grazers to predators. They often favour certain temperature regimes and current velocities and exhibit different life cycle patterns. While some species tolerate a wide range of ecological conditions, others are much more specific.

Ecological preferences of freshwater organisms, often referred to as "traits", are widely used as a tool for analysing freshwater biota. Besides their application in basic ecological research (e.g., food web analysis or ecosystem delineation) they are of particular importance for integrating freshwater ecological knowledge into water management practice. For more than a century the ecology of lakes and rivers has been investigated and monitored using benthic invertebrates, based on their sensitivity to environmental stresses such as organic pollution, acidity and others. More recently, complex systems for analyzing the ecological quality of freshwater ecosystems based on the ecological preferences of recorded species have been developed and implemented in many parts of the world. In Europe, in particular, the last few years have seen much development in stream assessment systems, as recent legislation demands novel integrative tools. Ecological preferences of freshwater organisms are also increasingly used for assessing and predicting the impact of climate change on the benthic communities of lakes and rivers (Durance & Ormerod 2007).

Despite a multitude of applications knowledge on freshwater organisms, their distribution, habitats, life cycles and indicator potential is still scattered and incomplete. Thousands of papers have been published in regional and "grey" literature, often restricted to single species and in many cases in a narrative form. However, for application in community ecology and ecosystem assessment, this information needs to be transformed into comparable data, for example numerical values.

In some European countries knowledge on the ecological preferences of benthic invertebrates have been summarized; the most comprehensive compilations relate to Austria (Moog 1995, 2002), Germany (Schmedtje & Colling 1996), France (Tachet et al. 2000) and Slovakia (Sporka 2003). Although they were originally restricted to individual countries, these compilations are now widely used in other parts of Europe.

The current book series aims to create an even more comprehensive approach: the evaluation of all available literature on the distribution and ecological preferences of se-

lected organism groups, widely distributed in European freshwater ecosystems, and the transformation of this information into a consistent, comparable format, which can be used within many European ecological assessment systems.

The data compilation results from a series of EU-funded research projects, in particular Euro-limpacs, an Integrated Project addressing the impact of climate change on European freshwater ecosystems (contract number GOCE-CT-2003-505540, www.eurolimpacs.ucl.ac.uk). Only a small fraction of the relevant literature that forms the basis of this compilation was published in ISI journals: the majority was published in regional journals in many different languages. Consequently, the contribution of experts from many countries was required to generate this book series; work that was only possible within the framework of a Pan-European project.

The series started with the compilation of autecological information on the orders Trichoptera (Graf et al. 2008) and Plecoptera (Graf et al. 2009).

Introduction to this book

This third volume of the book series summarizes the current knowledge on European mayflies (Ephemeroptera). Ephemeroptera are one of the oldest living order of winged insect and one of the most abundant taxonomic groups inhabiting European freshwater environments. This insect order is globally present with over 3000 species divided into 42 families (Barber-James et al. 2008). A recently compiled European mayfly checklist includes 18 families, 50 genera and 339 species distributed throughout Europe (Thomas & Belfiore 2004). Ephemeroptera constitute a key element in freshwater ecosystems as they are present in a broad assortment of habitats, display a wide range of ecological requirements and often contribute significantly to the secondary production of the benthic community (e.g., Sowa 1975, Hefti et al. 1985, Elliott et al. 1988). In addition, mayflies are often appropriate indicators for detecting many kinds of environmental change and ecosystem alteration (Usseglio-Polatera & Bournaud 1989, Bauernfeind & Moog 2000). The impact of different types of anthropogenic pressure on this taxonomic group has been extensively evaluated, that is organic pollution (e.g., Soldán et al. 1998), acidification (e.g., Guerold et al. 2000), trace metals (e.g., Malmqvist & Hoffsten 1999) and pesticides (e.g., Beketov & Liess 2005). However, only a few studies have been directly aimed at assessing the potential effects of climate change on species belonging to this insect order (e.g., McKee & Atkinson 2000). Moreover, in various European areas (e.g., southern and eastern Europe) still little is known about the taxonomy, distribution and ecology of most of the species (e.g., Buffagni & Belfiore 1994, Sartori 2001). In recent years, endemic species have been described (e.g., Belfiore & Desio 1995, Belfiore et al. 1997, Haybach & Thomas 2002, Bauernfeind 2003, Alba-Tercedor & Derka 2004) and many others have been recorded in areas where they were initially assumed to be absent (e.g., Malzacher 1986, Alba-Tercedor & Jaimez-Cuellar 2003). Nonetheless, relevant information is often restricted to specialist journals and identification keys are rarely up-to-date, which currently limits any progress in the acquisition of knowledge about mayflies on a European scale. Further taxa are known to exist but still have to be described (e.g., Buffagni et al. 2001, Pinto & Puig pers. comm.). In some cases, species currently considered as such may in fact be species complexes (e.g., *Baetis rhodani*). When new species are described, providing the basis for further investigations and therefore requiring high priority, attention is normally focused on morphological features in order to discriminate between the new taxon and any congeneric species. The definition of species' autecology is usually performed by subsequent investigations, i.e. based on larger datasets which, however, have only been collected for few species. In spite of the overall dearth of basic knowledge on mayflies, over the last few decades, a limited amount of funding has been directed to taxonomic, faunistic and autecological investigations in Europe: the es-

sential basis for any scientifically-sound and applied ecological study. Some positive signals have been observed recently with regards to the application of genetics to taxonomy only i.e. DNA barcoding (e.g., Hebert et al. 2003).

An in-depth evaluation of the literature shows that even a range of easily accessible papers, including extremely relevant information (e.g., Stendera & Johnson 2005, Bonada et al. 2005), did not permit a factual extrapolation of species-specific information, because relevant autecological data is presented in a synoptic form only. This may be the result of editorial policy among major scientific publishers who, owing to a lack of publishing space, do not require and/or allow the printing of detailed and extensive data summaries or to authors' lack of interest in publishing raw data, which they prefer to keep to themselves for later publications. Some major scientific journals (e.g., Nature) encourage the deposit of all raw data so as to guarantee data availability and the possibility of replicating experimental conditions but this is often not the case when processing and publishing manuscripts. Thus, in our opinion, to effectively aid the progress of autecological knowledge extension of benthic taxa, editors should encourage scientists to include as much raw information as possible in their manuscripts or in annexes. This would greatly increase the accessibility of basic ecological data.

In cases with a lot of information on a species available in papers from different parts of Europe, often collected using different approaches and scale resolution, drawing a general conclusion can prove arduous, both because of the differences in approach and geographical changes in the ecological preferences of species. In many cases the greatest difficulty arises when adapting information reported in papers based on small scale studies, i.e. very "local" points of view with a limited environmental range, and then having to compare them with a broader study, which covers the complete gamut of situations that may be experienced by the mayfly species on a European scale.

In this overall scenario, many scientific papers reviewed herein resulted in being high-quality data sources for extracting autecological information on mayflies. Relevant information is not automatically restricted to taxonomically focused papers and important records on the ecological preferences of mayflies were also extracted from documents dealing with larger parts or the whole benthic community (e.g., Soldán et al. 1998). Nonetheless, most information on mayflies was obtained from papers focusing on the order (e.g., Studemann et al. 1992, Bauernfeind et al. 1995, 2002, Bauernfeind & Humpesch 2001) or specifically addressing a single genus or one or few species (e.g., Maitland 1965, Buffagni & Gomba 1996, Studemann & Landolt 1997, Alba-Tercedor 2000, Gonzalez et al. 2001). As a general rule, the best results in acquiring ecological preference information are obtained if authors make a specific effort to summarize the relevant information presented in their paper by showing it in an extended tabular form.

Over the last 10-20 years, knowledge concerning the ecological preferences of benthic invertebrates including Ephemeroptera has been summarized in some European countries (see above). Although these comprehensive works have proven to be a fundamental contribution to European autecological knowledge (e.g., Bauernfeind et al. 1995, 2002, Schmedtje & Colling 1996, Haybach 1998), their compilation was generally based on expert systems,

which focused on local or national experiences rather than on the integration of European data. This study aims to provide a larger-scale perspective of the mayflies' ecological needs and preferences and includes the results presented in the above-mentioned reviews. The appraisal presented here is based solely upon published papers, i.e. the use of experimental data is only indirectly accounted for by extracting information from printed papers and authors' collections. However, in order to put conservation and management strategies into practice, the direct use of original, autecological data collected with uniformly analytical approaches presents major advantages, providing it is based on thorough taxonomical accuracy and on appropriate knowledge of the ecological attributes of the species (Hortal & Lobo 2006). Therefore, we hope that the autecological summary we propose here will be a useful starting point for further investigations throughout Europe and that the huge gaps on mayfly knowledge outlined here will be remedied with new experimental data collections. In general terms, a broad data analysis of the autecological preferences of mayflies on a European scale is advocated, in order to obtain a more complete picture of the autecological characteristics of the Ephemeroptera species. In addition the synoptic view of autecological traits of Ephemeroptera species presented in this book is useful for other purposes. First of all, it provides an easily accessible and comprehensive information database that will assist in the interpretation of any study focusing on the benthic community. The definition of species' ecological preferences constitutes the theoretical basis for the development of bioindicator systems, which are useful in ecological quality management and biodiversity conservation. Since the approval of the Water Framework Directive (WFD, 2000/60/EC; European Commission 2000) most European countries have begun the process of revising and adapting their river and lake assessment systems to cope with the Directive's requirements. The WFD currently aims at achieving good ecological status for all European water bodies by 2015 focusing on biological quality. The development of modern assessment systems requires selecting biological metrics or prediction elements that have broad diagnostic power. In other words, there is a need to define indicator species for the different sources of anthropogenic impact, for example organic pollution, metal contamination, morphological impairment or water abstraction. Within this framework, the database presented here could be of great support in obtaining information on the overall traits of potential indicators for different kinds of impact. Moreover, it could support the development of predictive assessment systems for benthic communities based on abiotic variables. The presented data may also be extremely useful in supporting conservation and biodiversity protection programmes. The notable absence of most of the vulnerable mayfly species and most other aquatic invertebrate species from the official European conservation database and legislation, i.e. the IUCN list (IUCN 2007) and the EU Habitat Directive (92/43/EC, European Commission 1992), should be revised and the information made available with this database could be used to specify an initial list of species that require protection in order to conserve European freshwater biodiversity. A regular update of the above mentioned and widely used official lists with reference to all sensitive mayflies and other aquatic invertebrate species is to be highly encouraged so that conservation strategies for vulnerable species can be implemented.

As far as climate change is concerned, the information presented here is only a starting point in the evaluation of its potential effects on various freshwater ecosystems. The main biological traits involved will be temperature and altitudinal preferences, the plasticity of life cycles (Harrington 2005) and, especially in southern European countries, an aptitude for colonizing intermittent rivers (Sabater et al. 2008). Life cycle is expected to be especially influenced because of its dependence on thermal regimes (Elliott 1987, Briers et al. 2004) and the necessary conditions for egg hatching, larval development and flight emergence periods. Altitudinal and latitudinal distribution ranges are also extremely relevant to the study of climate change effects. In the northern hemisphere, northern and southern limits of species will tend to move northward (e.g., Woiwod 1997). For instance, Hickling et al. (2005) observed that some thermophilic mayfly species may extend their northward distribution in Britain as a result of climate warming.

Regarding the ecological factors most relevant for Ephemeroptera a range of environmental conditions can greatly influence the distribution of the mayfly species and freshwater invertebrates in general. Hydraulic and morphological features are, for example, crucial in structuring the habitats of aquatic organisms in rivers (e.g., Statzner & Higler 1986, Parsons & Norris 1996) and undeniably influence major aspects in applied ecological issues (e.g., Cogerino et al. 1995, Buffagni et al. 2009a). Water velocity (Gore et al. 2001), turbulence (Hynes 1970, Mérigoux & Dolédec 2004, Brooks et al. 2005) and flow types (Urbanič et al. 2005) are among the variables that most influence taxa presence and distribution across habitats. In addition, channel substrate greatly controls invertebrate distribution (e.g., Cummins & Lauff 1969, Brookes 1988). Moreover, mayfly species inhabiting freshwater ecosystems are ectotherm and are thus highly dependent on water temperature fluctuations (Elliott 1987). In general terms, some species tolerate a wide range of ecological conditions, while others are much more specialized (Degrange & Sowa 1988).

This review constitutes a comprehensive picture of papers published until the end of 2007. Papers from all over Europe have been searched for and examined in order to guarantee a good coverage of different European geographical areas. Nevertheless, the results obtained would greatly benefit from the integration of knowledge from some more European areas, in which language barriers or problems with access to literature sources have limited the effectiveness of the review process (e.g., eastern countries). The review process itself should be considered as work in progress. Future collaboration with other taxonomic and ecological experts to integrate currently available literature datasets is to be greatly encouraged and would be highly appreciated for producing a joint and even more exhaustive review in future.

This book provides comprehensive information on the ecological preferences of European mayflies, based on the screening and evaluation of over 2800 literature references. In addition, the distribution within the European ecoregions is given for 344 mayfly species and sub-species. All data are additionally stored in an online database (www.freshwaterecology.info, Buffagni et al. 2007).