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Preface: Assessment of physical habitat characteristics in rivers, implications for river ecology and management

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ABSTRACT

Preface: Assessment of physical habitat characteristics in rivers, implications for river ecology and management

Physical habitat characteristics are an extremely important factors determining the structure and composition of fluvial biological communities and fluvial ecosystem functioning. Existing methods for characterising the physical realm of river habitats are increasingly important, not only for monitoring river ecosystem health and the success of river restoration projects but also for increasing the understanding of river ecosystem functioning and improving the efficiency of management actions. However, there is no scientific consensus on which methods to use for long-term monitoring and which river features to monitor because many fundamental questions relating hydrological, geomorphological and biological characteristics remain unanswered and because river habitats are monitored to cover a wide variety of objectives. Several initiatives worldwide have demonstrated the importance of analysing and discussing the application of different methods to assess river habitat characteristics for different objectives. It would be interesting to achieve a common approach for river habitat characterization for different objectives, especially for mid- to long- term monitoring programs and different river management issues (e.g., monitoring river restoration projects). More elusive but no less important is the contribution of these methods to understanding the interactions between river habitat architecture and river functioning. In this regard, the Physical Habitat Assessment Methods in Rivers (PHAM) seminar was organised in Santander, northern Spain, in November 2009 to review current practices on river habitat assessment. The contributions presented in that seminar and some later contributions form the basis of this special volume. These papers identify the main factors creating and maintaining river habitats, review physical habitat assessment methods and propose improvements and adaptations, apply different methods in distinctive geographical areas and characterise river habitats for estimating habitat availability of different fish species.

Key words: River habitat assessment, River monitoring, Hydromorphology, Water Framework Directive.

RESUMEN

Prefacio: Valoración de las características del hábitat físico en ríos. Implicaciones para la ecología de ríos y su gestión

Las características físicas del hábitat son un factor extremadamente importante que determina la estructura y composición de las comunidades biológicas fluviales y también juegan un papel importante en la determinación del funcionamiento del ecosistema fluvial. Los métodos actuales que caracterizan la realidad física de los hábitats fluviales son cada vez más importantes, no sólo para monitorear la salud del ecosistema fluvial y el éxito de los proyectos de restauración, sino también para aumentar la comprensión del funcionamiento del ecosistema fluvial y la mejora en la eficiencia de las acciones de gestión. Sin embargo, el consenso científico sobre qué métodos utilizar y que características del río monitorizar a medio y largo plazo está lejos de ser alcanzado, debido a que muchas cuestiones fundamentales que relacionan las características hidrológicas, geomorfológicas y biológicas siguen sin respuesta y porque los hábitats fluviales se monitorean para cubrir una amplia variedad de objetivos. Diferentes iniciativas en todo el mundo han mostrado la importancia de analizar y discutir la aplicación de diferentes métodos para evaluar las características del hábitat del río para diferentes objetivos. A este respecto, sería interesante poder lograr un enfoque común para la caracterización del hábitat del río con relación a diferentes objetivos, especialmente en lo referente a programas de vigilancia a medio y largo plazo y a diferentes problemas de gestión fluvial (por ejemplo, monitorización de proyectos de restauración fluvial). Más difícil de alcanzar, pero no menos importante es la *necesidad de comprender las interacciones entre la arquitectura y el funcionamiento del hábitat fluvial del río. En este sentido, el seminario Physical Habitat Assessment Methods in Rivers (PHAM) fue organizado en Santander, norte de España, en noviembre de 2009, para examinar las prácticas actuales en la evaluación del hábitat fluvial. Las contribuciones presentadas en el seminario y algunos trabajos posteriores forman la base de este volumen especial. Los trabajos incluidos aquí, identifican los principales factores en la creación y mantenimiento de los hábitats fluviales, revisan los métodos de evaluación del hábitat físico y proponen mejoras y adaptaciones, presentan aplicaciones en diferentes áreas geográficas y comparan los resultados y caracterizan el hábitat fluvial para estimar la disponibilidad de hábitat de diferentes especies de peces.*

Palabras clave: *River habitat assessment, River monitoring, Hydromorphology, Water Framework Directive.*

INTRODUCTION

Fluvial systems provide natural resources (e.g. fish and clean water) as well as cultural and ecological services (e.g. transportation, energy, irrigation, recreation and waste assimilation) basic to human societies (Naiman *et al.*, 2002). At the start of this century, large dams approximately contributed to 20 % of the world's electricity supply, and irrigated agriculture produced 40 % of the world's food (Gleick, 1998). Use of fluvial natural resources has resulted in the loss of more than 40 % of their biodiversity, thereby compromising their natural functioning (Millenium Ecosystem Assessment, 2005). Water shortage and the loss of freshwater ecosystem services may affect 40 % of the world's population by 2050 (Millenium Ecosystem Assessment, 2005).

Sustaining or restoring the natural functioning of water-dependent ecosystems is crucial for human welfare and, in the face of continuing growth of human population and water demands, constitutes a challenging task (Postel & Ritcher, 2003). Moreover, fluvial ecosystems are the subject of many conflicts of interests. In Europe, for example, hydropower is promoted as a source of renewable energy (Ringel, 2006), while many river habitats and species are protected in the Natura 2000 network under the EC Habitats Directive (HD; EC, 1992). Furthermore, the EC Water Framework Directive (WFD; EC, 2000) requires that all European water bodies achieve good ecological status or good ecological potential by 2015 (Achleitner *et al.*, 2005), while the Floods Directive (EC, 2007) obliges all Member States to develop flood risk management plans by 2015. Thus, the number of river restoration and river engineering schemes is expected to increase in the coming years in order to meet the demands from the different European directives. Water managers will have to decide on the best solutions in order to achieve the desired conditions. However, the ecological consequences of manipulating multiple physical elements such as hydrological regimes and stream hydraulics is not fully understood and has not been properly quantified (Naiman *et al*. 2002). Moreover, at a time when water administrations are facing such important challenges, land use planning, ecological restoration and fluvial engineering should not be exclusive alternatives. They should complement each other to offer decision makers other non-structural solutions, which may be less expensive and much more effective (e.g., Kronvang *et al.*, 1998; Blackwell & Maltby, 2006). For example, flood risk management plans must include measures that facilitate natural processes such as maintenance and/or restoration of floodplains in order to give back space to the rivers wherever possible. The implementation of these measures requires a deep understanding of river processes and cause-effect relationships among hydrology, hydraulics and biological communities.

Lack of hydrological, geomorphological, chemical and biological data in many catchments is one of the major handicaps to understanding the interactions between these ecosystem components. If scientific progress is to unravel the interactions between hydrological, geomorphological and biotic processes, river research needs to adopt new approaches to overcome the frequent mismatch between the nature and the spatio-temporal resolution of the available environmental data. This disparity stems from different primary purposes for data collection (Monk *et al.*, 2007). Moreover, the cause-effect relationships can be elucidated with a proper spatio-temporal framework and experimental designs (Downes *et al.*, 2002). Few databases, however, have been designed with that specific purpose. In this regard, complex databases that integrate long-term hydrological, geomorphological, chemical and biological characteristics must be developed in order to determine the ecological responses to multiple or cumulative effects (Naiman *et al.*, 2002; Ormerod *et al.*, 2010).

One of the major challenges in river ecology and management is identifying river reaches where hydrological and geomorphological characteristics are similar and maintained by comparable river processes, so that proper hypothesis testing and management units can be established (Thorp *et al.*, 2006; Poff *et al.*, 2010). Moreover, every theoretical and empirical construct related to the dynamics of freshwater ecosystems identifies hydrology and sediment movement as being fundamental to physical habitat creation and maintenance (Ritcher *et al.*, 2006). Physical habitat characteristics constitute an important factor that controlls the structure and composition of fluvial biological communities and they may also play an important role in determining fluvial ecosystem functioning (Dent *et al.*, 2002; Murray *et al.*, 2008). Physical habitat characteristics are among the most common targets in many restoration programs (Palmer *et al.*, 2010). Thus, methods characterising river habitats are becoming more important not only for monitoring river ecosystem health and the success of river restoration projects but also for increasing the understanding of river ecosystem functioning and improving the efficiency of management actions.

National and/or regional monitoring programs are among the few sources of data that may be available to undertake long-term studies that allow advancing in the understanding of complex ecological interactions. However, there is no scientific consensus on the methods for mid- to long-term monitoring and which river features should be monitored. We believe the most important reasons for this lack of consensus are: (1) many fundamental questions relating hydrological, geomorphological and biological characteristics remain unanswered; and (2) river habitats are monitored to cover a variety of different objectives depending on the administrative entity and legal requirements, thus, different habitat characteristics are targeted depending on objectives.

This fact contrasts with the better established methods to estimate physical habitat availability for aquatic organisms in the frame of environmental flow studies (e.g., Ginot, 1995; e.g., Bovee *et al.*, 1998; Hardy & Williamson, 1999; Jowett, 1999). Such methods facilitate the comparison of results from different catchments and the integration of data that have been gathered using consistent methods at the basin scale (e.g., Bartholow & Waddle, 1986). More detailed methods, such as habitat modelling, are recommended when environmental flows need to be defined (Dyson *et al.*, 2003). In such studies, prioritization of a clear objective and the identification of research needs from a multidisciplinary point of view to the development of new methods in the 1970 (Nestler *et al.*, 1989) and to the subconsequent investments in relevant ecological studies. This example demonstrates that when there are clear environmental objectives, it is much easier to propose methods that can be applicable to wider geographical areas and river types.

Some attempts have been made to standardize, analyse and discuss methods for assessing river habitat characteristics. These include the publication of a European standard for assessing the hydromorphological characteristics of rivers (CEN, 2002) and the development of the Physical and Chemical Assessment Module (University of Canberra, 2000), within the Australian River Assessment System (AusRivAS), which aims to build up a river habitat assessment methodology with predictive capacity at different spatial scales. More recently, the importance of hydromorphological characteristics to ecological river functioning have been discussed in a meeting held in Ballater, Scotland (http://www.macaulay.ac.uk/hydroworkshop/). Finally, a special volume dedicated to recent developments in the classification, assessment and management of freshwater habitats in Britain and Europe has been published (Raven & Diamond, 2010). These individual initiatives worldwide have highlighted the importance of analysing and discussing the application of different methods to assess river habitat characteristics for different objectives. In that regard, it would be interesting to achieve a common approach for river habitat characterization for different objectives, specially regarding mid- to long- term monitoring programs and different river management issues (e.g., monitoring river restoration projects). Very important yet elusive is to analyze the contribution of these methods to the understanding of the interactions between river habitat architecture and river functioning. To this end, the Physical Habitat Assessment Methods in rivers seminar (PHAM) was organised in Santander (November, 2009) with the aim of complementing previous works with experiences from the Iberian Peninsula and other parts of Europe (http://www.riverhabitats.org/Inicio.aspx). The objectives of this seminar were (1) to review which fluvial processes are important in the creation and maintenance of river habitats, (2) to review a selection of methods employed in the European Community to assess physical habitat characteristics in rivers and (3) to analyse which variables might be the most relevant ones to include in mid- to long- term monitoring programs. This special issue compiles most of the contributions from that seminar and other contributions that were prepared after the seminar and that covered a variety of topics related to the characterisation of river habitats.

SPECIAL ISSUE CONTENT

The first two papers of this special issue examine the definition of river habitats from an ecological perspective and the identification of the environmental factors and river processes that are important for creating and maintaining river habitats at the catchment (Ibisate *et al.*, 2011) and reach (Elósegui *et al.*, 2011) scales. The third paper investigates how the accuracy of derived river networks from different digital elevation models (DEM) affects the ability to explain patterns on river habitat characteristics (Peñas *et al.*, 2011).

The first paper of the following set is a review of methods used to characterise river habitats in Europe, Australia and United States based on how they deal with different issues such as spatial scales, river zones, physical features included, method accuracy and geographical applicability (Fernández *et al.*, 2011). Many of the methods characterising river habitats in the Iberian Peninsula and elsewhere in Europe have already been applied to a wide variety of river types and in different geographical settings. This process has identified deficiencies in their application or the need to adapt so that they can be applied outside the area for which they were developed. In this regard, new versions of the Riparian Quality Index (RQI; González del Tánago & García de Jalón, 2011), the index for hydromorphological quality assessment (IHG; Ollero *et al.*, 2011), and the "Índice de Conectividad Fluvial" (ICF, Solà *et al.*, 2011) are presented and an adaptation of the River Habitat Survey protocol for its application to Portuguese rivers is also included (Ferreira *et al.*, 2011).

Another set of papers explore the comparison and application of river habitat characterisation methods in Central Europe and different parts of the Iberian Peninsula. The performance of the EcoRivHab and LAWA-OS methods is compared in the Bílina river in the Czech Republic (Matouskova & Dvořák, 2011), while QBR ("Qualitat del Bosc de Ribera") and IHF ("Índice de Habitabilidad Fluvial") indices are used to describe hydromorphological and riparian characteristics along with a floristic inventory along the Serpis River in Valencia (Garófano-Gómez *et al.*, 2011). This set also includes a comparison of the results obtained by riparian (QBR and RQI) and instream habitat characterisation protocols (IHF and HQA: Habitat Quality Assessment from the RHS) applied to the Cantabrian rivers northern Spain (Barquín *et al.*, 2011). Finally, this set includes an original analysis on the effects that land use fractal metrics have on river reach characteristics and on macroinvertebrate communities, in rivers of northern Portugal (Cortes *et al.*, 2011).

The last set of papers to this special volume examines river habitat characterisation and modelling from the perspective of stream fish communities or populations. In this regard, (Alcaraz-Hernández *et al.*, 2007) analysed the spatio-temporal variability of mesohabitats in four Mediterranean rivers of the Júcar River Basin. In the Tajuña River (Tagus River Basin), the MesoHABSIM tool was used to model brown trout habitat availability, while restoration measures were evaluated based on benefits to trout habitat (Gortázar *et al.*, 2011). Refuge cover and substrate were included in simulations of habitat availability for two cyprinid species in the Arade basin southern Portugal (Boavida *et al.*, 2011), with the aim of evaluating channel enhancement alternatives. The final paper in this set uses a variety of methods to assess longitudinal connectivity for fish in artificial barriers of six Catalonian rivers (Ordeix *et al.*, 2011).

The last paper of this special issue closes with a reflection on how to develop more effective approaches for river habitat monitoring and modeling to improve the understanding of river ecosystem functioning. This work is based on collaborative experiences with universities, consultancies, and different administrative bodies responsible for the delivery of the Water Framework Directive (Naura *et al.*, 2011).

PERSPECTIVES: ASSESSING COMPLEXITY

The purpose of this special volume was to provide a summary of existing methods to characterise river habitats and also to review the basic concepts and knowledge related to the characterisation of physical attributes of river habitats. Many of the methods that have been referenced in these papers have been used for more than a decade and have been modified for use in different river types over wider geographical areas. The primary aim of many of the methods described was to satisfy different environmental legislation needs (e.g., WFD) or management priorities (e.g., environmental flows), rather than originating from research programs designed to investigate river geomorphological dynamics.

However, in the last decade the study and modelling of river morphodynamics have become well-known and many technologies are now employed with promising results for river habitat characterisation (e.g., James *et al.*, 2007). For example, these techniques include the acoustic doppler current profiler (ADCP) and the acoustic doppler velocimeter (ADV), systems that provide accurate water velocity profiles and water depths, and particle image velocimetry (Meselhe *et al.*, 2004), which accurately estimates surface water velocities and river flow in a relatively automated manner (Pimentel, 2007). Moreover, the use of techniques such as Laser Imaging Detection and Ranging (LIDAR) and the laser scanner allow us to get precise geomorphic information of relatively extensive areas. Satellite images are used with increasing frequency to investigate forest dynamics (Antonarakis *et al.*, 2011) and have been used to study riparian community structure (Antonarakis, 2010). This is also the case for multispectral imagery, although its applications to riparian forest are still scarce (Davis, *et al.*, 2002).

Characterising physical attributes of river habitats and the effects of human impacts on them is a complex task. It is challenging because different characteristics may need to be recorded at different spatio-temporal scales. Characterising the complexity of river habitats in a precise and consistent manner and covering large geographic areas might only be affordable with the use of the new technologies. However, the implementation of these technologies has some constraints, including the relatively high associated cost and the computational requirements for handling large data outputs. Despite this, management actions should be based on the diagnosis produced and on the understanding of complex ecological processes. Thus, the more precise and accurate the diagnosis is, the higher the likelihood that the investment in management actions is not wasted. There are already a number of different examples that use remote sensing techniques to assess river morphology (Faux *et al.*, 2009; Ruffing & Daniels, 2011) and riparian vegetation (Magdaleno *et al.*, 2010) with promising future applications for river monitoring.

We believe that important advances in the characterisation of physical habitats in rivers are going to be possible thanks to the existing knowledge acquired with previous methods and the results of the extensive application of new technologies. Therefore, with the available knowledge and tools, it is very important that scientists and managers work together, in order to further advance towards more detailed environmental objectives regarding river habitats. This cooperation will help to develop a consensus for the mid- to long- term monitoring of river habitat characteristics, which is essential to increase our knowledge of river ecosystem functioning and to improve the effectiveness of river management actions.

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