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Adapting and adopting River Habitat Survey: Problems and solutions for fluvial hydromorphological assessment in Portugal

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ABSTRACT

Adapting and adopting River Habitat Survey: Problems and solutions for fluvial hydromorphological assessment in Portugal

The Water Framework Directive (WFD), which established the use of hydromorphological quality elements to assess the ecological status of water bodies, has influenced the purpose and content of several European methods for characterizing physical structure and assessing habitat quality in rivers. The River Habitat Survey (RHS) is a WFD compliant method developed in the UK and follows rapid and simple survey procedures using a standardised approach to characterize the physical habitat and evaluate hydromorphological quality. In Portugal, RHS was adopted for WFD purposes due to its successful long term application across the UK and other European countries. Even so, an effort was made to adapt the RHS to Portuguese regional and river characteristics, in order to accurately record habitat features, assess habitat quality and comply with legal requirements. This paper describes the constraints, adaptations, state of the art and way forward for a successful RHS implementation in Portugal. Constraints concerning the application of RHS to Mediterranean rivers are strongly related to natural hydromorphological processes, namely annual and inter-annual flow variability, which is a potential source of covariance with anthropogenic pressures. This leads to difficulties in recognizing and accurately recording some RHS features. Adaptations to RHS were introduced for survey guidelines, recording procedures and improved definitions of habitat features. Additional modifications were prepared in different sections of RHS field form to reflect Portuguese river features and incorporate components required by the WFD.

Key words: Water Framework Directive, ecological status, hydromorphological quality assessment, Mediterranean rivers, lotic habitat features, RHS adaptations.

RESUMEN

Adaptando y adoptando River Habitat Survey: problemas y soluciones para la valoración de la hidromorfología fluvial en Portugal

La Directiva Marco del Agua (DMA), que estableció el uso de indicadores de calidad hidromorfológicos para evaluar el estado ecológico de las masas de agua, ha influido en la finalidad y el contenido de varios métodos europeos para la caracterización de la estructura física y la evaluación de la calidad del hábitat en los ríos. El River Habitat Survey (RHS) es un método compatible con la DMA desarrollado en el Reino Unido y sigue los procedimientos de encuesta rápida y sencilla utilizando un método estándar para caracterizar el hábitat físico y evaluar la calidad hidromorfológa. En Portugal, el RHS

fue adoptado a efectos de la DMA debido a su exitosa aplicación a largo plazo en el Reino Unido y otros países europeos. Aun así, se hizo un esfuerzo para adaptar el RHS a las características regionales y de los ríos de Portugal, con el fin de registrar con precisión las características del hábitat, evaluar la calidad del hábitat y cumplir con los requisitos legales. Este artículo describe las limitaciones, las adaptaciones, el estado de implementacion y la manera para una implementación exitosa de RHS en Portugal. Las restricciones relativas a la aplicación de RHS a los ríos del Mediterráneo están fuertemente relacionadas con procesos hidromorfológicos naturales, como es la variabilidad del flujo anual e interanual, la cual es una fuente potencial de covarianza con presiones antropogénicas. Esto lleva a dificultades para reconocer y registrar con precisión algunas de las características del RHS. Se han introducido adaptaciones al RHS en las directrices de muestreo, en los procedimientos de registro y se han mejorado algunas definiciones de ciertas características del hábitat. Otras modificaciones adicionales se han realizado en diferentes secciones del formulario de campo del RHS para reflejar las características de los ríos por tugueses y ciertas componentes requeridas por la DMA.

Palabras clave: *Directiva Marco del Agua, Estado ecológico, Evaluación de la calidad hidromorfológica, Ríos mediterráneos, Características del hábitat lótico, Adaptaciones al RHS.*

INTRODUCTION

The Water Framework Directive (WFD, Directive 2000/60/EC, European Commission, 2000) establishes that EU Member States shall protect, enhance and restore aquatic environment through the implementation of programmes of measures developed and implemented as part of river basin management plans in order to maintain or achieve good water status by 2015. This is achieved when both ecological status and chemical status are at least good. Ecological status is an expression of the quality and function of aquatic ecosystems and is classified considering Biological Quality Elements (BQE) and the hydromorphological, chemical and physico-chemical elements that support them (European Commission, 2000).

The WFD introduced an obligatory hydromorphological quality element to assess the ecological status of European rivers, for environmental planning, monitoring, reporting and improving ecological quality where necessary (Boon *et al.*, 2010; Raven *et al.*, 2002). This unparalleled normative recognition of the influence of river physical habitat characteristics in the structure of biotic systems, underlines its importance in ecological classification of river systems (Raven *et al.*, 2002). Hydromorphological quality elements are based on the hydrological regime, river continuity and morphological conditions (European Commission, 2000; Table 1). The WFD also explicitly states that monitoring shall conform to existent and relevant national or international standards (European Commission, 2000; Boon *et al.*, 2010). The European Committee of Standardization (CEN) has developed two relevant standards for assessing river hydromorphology: EN 14614, a guidance standard for hydromorphological features assessment (Instituto Português da Qualidade, 2004) and EN 15843, a guidance standard on determining the degree of modification on river hydromorphology (Instituto Português da Qualidade, 2010).

Several methods for characterizing the physical structure of rivers and assess habitat quality have been independently developed across Europe since the early 1990s, although implementation of the WFD has inevitably influenced their overall purpose and specific content (Raven *et al*, 2002). The River Habitat Survey (RHS) from the UK (Environment Agency, 2003), the Système d'Evaluation de la Qualité du Milieu Physique (SEQ-MP) from France (Agence de l'Eau Rhin-Meuse, 1996), and the field survey method of the Länderarbeitsgemeinschaft Wasser (LAWA-vor-Ort) from Germany (LAWA, 2000) served as the basis for the development of the CEN standard EN 14614 (Instituto Português da Qualidade, 2004).

Historically, river characterization in Portugal has been based on hydraulic engineering concepts related to improving water management

Table 1. WFD hydromorphological quality elements, components and RHS compliance. *Elementos y componentes de calidad hidromorfológica establecidos en la DMA y compatibilidad del RHS.*

Hydromorphological Elements	**Component**	**RHS compliance**
Hydrological regime	- Quantity and dynamics of river flow	RHS only assesses dynamics of river flow
	- Connection to groundwater bodies	Not assessed by RHS
River continuity		RHS assesses river continuity but only within 500m. For a broader scale (*e.g.* waterbody) it has to be complemented by other sources of information (*e.g.* GIS) or by carrying out several continuous surveys
Morphological conditions	- River depth and width variation	Not assessed by RHS
	- Structure and substrate of the river bed	Assessed by RHS
	- Structure of the riparian zone	Adaptations to RHS form can allow assessment of this component

capacity for societal end use such as potable supply, irrigation and hydroelectric generation or preventing negative effects such as flood events (Cardoso, 1998). The first attempts to describe river habitat modification in Portugal were made at the beginning of the 1990's, in association with research projects on limnology and aquatic ecology (Cortes, 1989, Ferreira, 1992). Instead of using global indices to assess human disturbance, these studies combined different relevant environmental descriptors to establish links between the river biota and geomorphological/hydromorphological modifications. Further efforts to develop habitat classification systems were developed based on these initial studies and limnological empirical knowledge. Limited to descriptions of in-stream conditions, the Channel Quality Degree (GQC; Cortes *et al.*, 1999) was developed to characterize and assess stream physical quality. Tools based on the composition and structure of riparian vegetation as indicators of ecological quality were also published (Ferreira *et al.*, 2002).

Afterward, it became more frequent to apply other European methodologies, such as the Riparian Forest Quality index (QBR; Munné *et al.*, 1998; 2003), and RHS (Raven *et al.*, 1997; 1998). RHS was first used on the island of Madeira by Hughes (2003) followed by Cortes *et al*. (2004, 2008a) on the Portuguese mainland with the purpose of identifying priority areas for restoration measures along disturbed rivers. Simultaneously, other integrated attempts to produce indices have combined physical habitat descriptors and water quality parameters (e.g., IMH: Oliveira & Cortes, 2004; or HCI: Oliveira & Cortes, 2005) or GIS tools to integrate monitoring data results, environmental descriptors and relevant spatial information, extrapolating findings along the fluvial network to reflect large scale impacts (e.g., KT system: Cortes *et al.*, 2002; Fernandes *et al.*, 2007). Currently, detailed habitat description and physical characterization are used to identify potential factors that explain biotic distribution patterns (see recent works by Hughes *et al.*, 2008 for southern catchment basins and Cortes *et al.*, 2009 for northern catchment basins).

Since no standard national hydromorphological assessment protocol existed before WFD implementation, the Portuguese Water Authority evaluated WFD requirements, national expertise and available methods in order to select the official hydromorphological sampling method. The final resolution was to adopt the RHS method as a tool for hydromorphological monitoring and assessment of river habitats. Given the absence of historical monitoring programmes of hydromorphological quality, limited available expertise, along with the natural constraints and diversity of rivers, there was a need to define a short-to-long term work plan to implement RHS as an official hydromorphological quality assess-

ment tool in Portugal. This paper describes the state of the art and way forward for RHS implementation in Portugal. We list and discuss necessary RHS adaptations and describe work in progress for nationwide implementation.

REGIONAL AND RIVER CHARACTERISTICS IN PORTUGAL

Mainland Portugal is characterized by a highly diverse landscape despite its small area (89 000 km^2). Climate, relief and geology act together to produce a wet, mountainous North and a relatively flat, warm and dry South, divided by the Tagus river basin. According to the Köppen-Geiger's updated classification (Peel *et al.*, 2007), Portugal's mainland climate is essentially Mediterranean (*Csa* and *Csb*), influenced by its position on the Atlantic and proximity to the Mediterranean, the compact form of the Iberian Peninsula and the nature of the peninsula's relief. The influence of the Atlantic generates a mild climate with a narrow temperature range and high levels of atmospheric humidity, particularly in the northwest regions. The Mediterranean influence leads to long summers with high annual mean temperatures and extreme aridity, with small amounts of variable, erratic rainfall occurring all year round, mostly south of the Tagus River, but also in the centre and north-east region. The biogeography of Portugal's mainland is predominantly Mediterranean, but also comprises a north-west Eurosiberian region (Atlantic sub-region; Costa *et al.*, 1998). The lithology is mostly siliceous, with calcareous areas located on the centre littoral and south (Algarve and Alentejo; Alves *et al.*, 2002).

This environmental complexity and diverse landscape is reflected in Portugal's river hydrology and morphology (INAG, 2002), resulting in a large number of river types (INAG, I.P., 2008) separated by factors such as flow discharge, flow regime, substrate type and composition, and water chemistry. Intermittent Mediterranean rivers are a good example of this hydromorphological complexity. These fluvial systems are characterised by a predictable annual cycle of flood and drought that varies in intensity according to the levels and duration of annual and inter-annual rainfall (Gasith & Resh, 1999; Pires *et al.*, 2004; Bêche & Resh, 2007; Bonada *et al.*, 2007). This type of flow regime acts as a severe environmental filter and ecological constraint, influencing water physical and chemical characteristics, thereby shaping biological community traits (Poff, 1997; Statzner *et al.*, 2004; Bonada *et al.*, 2005). These harsh environmental factors make it hard to separate the effects of natural hydromorphological processes from those resulting from anthropogenic pressures, increasing the difficulty of accurately record hydromorphological features and assess ecological quality (Raven *et al.*, 2009; Hughes *et al.*, 2009). Moreover, Iberia's Mediterranean rivers have a long history of human intervention, including intensive agriculture and forestry, damming, abstraction and urbanisation, resulting in habitat degradation and compromised structure and function in systems already subject to a harsh natural seasonal cycle of drought and flood (Aguiar & Ferreira, 2005; Hooke, 2006; Hughes *et al.*, 2008).

WHY RIVER HABITAT SURVEY IN PORTUGAL?

As part of the national WFD implementation process, the Portuguese Water Authority established a series of collaborative projects with Portuguese Universities to develop ecological quality assessment tools. The projects carried out from 2003 to 2006 and involved pressure analysis and biological, physico-chemical and physical habitat characterization of 435 sites. The main tasks were: i) the development and validation of a national river typology; ii) harmonisation of biological quality elements sampling methods; iii) establishment of a suitable hydromorphological survey method; iv) description of type-specific reference conditions; v) selection of pressure responsive metrics for each BQE; vi) establishment of an ecological quality assessment system.

Based on available national expertise QBR, GQC and RHS methodologies were considered the best candidates to be selected as official methods.

Importantly, RHS had been already used for several purposes such as the STAR project (Furse *et al.*, 2006), national research projects (Hughes, 2003; Cortes *et al*., 2004; Cortes *et al*., 2008a, 2008b) and environmental impact assessment studies.

Based on geomorphological principles, RHS uses functional information on available habitats and biotopes to link physical habitat with the biota. The RHS methodology was developed in the UK to characterise and assess, in broad simple terms, the physical character of freshwater streams and rivers along a 500 m length of river through the record of substrate and flow type, bank and channel natural features and modifications, land use, presence and complexity of riparian vegetation, together with measurements of stream and bank dimension. Observations on bank and channel features and modifications, land-use and channel vegetation types are made at ten equally spaced spot-checks situated at 50 m intervals, together with an overall "sweep-up" summary for the whole site. Other information such as valley form, bank profiles, features of special interest and notable nuisance plant species is also recorded (Environment Agency, 2003; Raven *et al.* 1997; Raven *et al*., 2009). Hydromorphological river quality is expressed via the Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS) indices, calculated from RHS survey information. HQA provides a broad indication of overall habitat diversity provided by natural features in the channel and river corridor, whereas HMS is an indication of artificial modification to river channel morphology (Raven *et al*., 2009).

The decision to adopt RHS methodology was supported on several reasons: i) RHS methodology was a major contributor to the CEN guidance standards EN 14614 and EN 15843 (Instituto Português da Qualidade, 2004; 2010); ii) experience in RHS application and validation in the UK dates back to 1994 (Raven *et al.*, 2009); iii) the method has been successfully used across most of Europe, showing that it can be adapted for general use outside the UK (Raven *et al.*, 2009); iv) RHS is partially compliant with some WFD normative definitions for hydromorphological quality elements; v) RHS comprises a standardised approach based on a strict field protocol, clearly defined quality control procedures, and surveyors are required to be fully trained and accredited (Raven *et al.*, 2009); vi) RHS follows rapid and simple sampling procedures (Raven *et al.*, 2009); vii) RHS is effective for detecting hydromorphological degradation on Portuguese rivers (Hughes *et al*, 2008); viii) RHS outputs are easily understood by managers, scientists and community groups; ix) RHS has many applications beyond the scope of WFD. Even so, considering the WFD normative definitions, it was clear that there is no single method able to provide answers to all the required factors of hydromorphological quality elements (*c.f.* Table 1). Therefore, an integrated approach that provides a true response to legal requirements is necessary (Raven *et al*, 2009).

RHS IMPLEMENTATION STRATEGY

In order to implement RHS as an official tool for the assessment of components of the hydromorphology quality element in Portugal, a short-to-long term work plan was defined (Table 2). Bearing in mind the experience and data available from above mentioned projects, adaptations of the RHS form and methodology were required in order to incorporate the identified differences between Portuguese and UK rivers and to fulfil some WFD requirements not covered by the original methodology. Nevertheless, a main goal

Table 2. RHS implementation procedures in Portugal and time scope. *Procedimiento de implementación del RHS en Portugal y escala temporal.*

Implementation Procedures	Time Scope
Adaptations of RHS form and methodology	Short term
Development of a Portuguese RHS manual	Short term
Implementation of national wide RHS training courses	Medium term
Development of a RHS database	Long term
Adaptation of HQA and HMS	Long term

was to adapt RHS with no major changes to the original methodology, thus allowing comparison of data between different Member States that use RHS. Afterward, the established milestones were to publish a Portuguese version of RHS field manual and to increase the number of accredited surveyors, by raising training capabilities in Portugal.

At a broader scale other steps were underlined as crucial: the development of a national database for compilation and quality control of RHS data collected through water status monitoring programs; the development of new indices or the adjustment of existing quality indices (HQA and HMS) derived from RHS data, as these indices were developed for UK river characteristics lacking accuracy and suitability to assess habitat quality in Portuguese rivers. In view of the previous analysis and defined work-plan, the Portuguese Water Authority is presently working on the short and medium term milestones and setting up self-building capacity to achieve long term objectives, in order to successfully implement RHS as one of the WFD hydromorphological quality assessment methods.

RHS APPLICATION AND ADAPTATION TO PORTUGUESE RIVERS: PROBLEMS AND SOLUTIONS

There are well-known difficulties in applying RHS to Mediterranean rivers and adaptations have been developed for southern Europe (Buffagni & Kemp, 2002). Some of the difficulties encountered using the RHS methodology in Portugal are strongly related to the natural hydromorphological processes associated with intermittent Mediterranean Rivers, namely river flow variation, which can be in some cases influenced by processes resulting from human intervention. In these cases high annual and interannual flow variability increases the difficulties of recognizing and accurately recording RHS features. Namely, macrophyte growth, substrate type and composition, flow types, erosion and depositional features are directly affected (Table 3).

Some changes on the original RHS form are directly linked with flow variability in Mediterranean rivers and consist of improved survey guidelines, the modification of some original RHS descriptions and the inclusion of new features to improve accuracy of river habitat characterization. These are currently being implemented via the Portuguese version of RHS field manual. Other adaptations comprise necessary minor adjustments to Portuguese lotic conditions and the re-definition of descriptions covering Land Use Categories, Special Features and Notable Nuisance Plant Species. Moreover, RHS methodology does not consider all WFD requirements and while some cannot be at all covered by RHS alone (*e.g.* quantity of water flow, connection to groundwater bodies), others, such as riparian vegetation structure, could easily be added into a RHS form (*cf.* Table 1). Thus adaptations regarding riparian vegetation have also been integrated in the Portuguese version of the RHS form.

RHS TRAINING, DATABASE DEVELOPMENT AND QUALITY INDICES: PRESENT AND WAY FORWARD

The adaptations mentioned above result from prior experience and data collected from studies using RHS in Portugal, but also from a 2009 collaborative field study with UK Environment Agency staff to several Portuguese intermittent Mediterranean Rivers (see Raven *et al*, 2009).

In collaboration with Environment Agency, the Portuguese Water Authorities held the first Portuguese RHS accreditation course in 2009. During 2010, a group of Portuguese RHS accredited surveyors attended a course in the UK, organized by the Environment Agency, allowing Portuguese Water Authorities to organize and give recognised RHS accreditation courses in Portugal. A new Portuguese RHS accreditation course is scheduled for 2011.

In 2011 the Portuguese Water Authorities will start developing a national RHS database. This database will allow accredited surveyors to input data from adapted RHS surveys and to compute RHS based indices. The future database will also include quality assurance routines to

Table 3. Main problems detected when applying RHS methodology to Portugal and solutions implemented (modifications to RHS field form in bold). *Principales problemas detectados al aplicar la metodología del RHS en Portugal y soluciones implementadas (En negrita las modificaciones realizadas al formulario del RHS).*

Features	Problems	Solutions
Seasonal and interannual flow variability	Mediterranean rivers are characterized by high seasonal and interannual flow variability. This directly affects RHS recorded habitat features such as macrophyte growth, substrate, flow types, etc. This can lead to different results depending on the time of year of survey.	Improved guidance on optimal season of survey; surveyors are required to always record the conditions of the survey.
Extensive side bars	Frequently some sites present very large side bars that extend through several spot-checks.	**Record the total number of side bars.**
Minor fords and weirs	During low flow conditions it is sometimes difficult to assess the real impact of such features.	Improve description of artificial features; improved guidance to evaluate real impact during training; improved guidance on time of survey.
Channel substrate diversity	Annual flow variability affects substrate characteristics leading to a high number of substrate types in a site.	Record both the dominant and **sub-dominant channel substrate.**
Sub-channels	Sub-channels are a common feature in Mediterranean rivers where seasonal flow has high variability. These shouldn't be mistaken with braided channels which are rare in Portugal.	**Record the presence and number sub-channels with water and dry sub-channels.**
Mid-channel bars and mature islands	Recording of mid-channel bars and mature islands during low flow conditions is difficult especially in partially dry rivers.	Improved guidance on time of survey; **distinction between mid-channel bars and mature islands surrounded by dry and wetted sub-channels.**
Extent of trees and associated features	The structure of the riparian zone is one of the WFD hydromorphology quality elements which is not entirely assessed by the original RHS.	**Adaptation of the "Extent of trees and associated features" section to record woody species composition and the width of riparian zone.**
Features of special interest-vernal pools	Extreme variation in seasonal flow regime often results in dry channels with vernal pools. This feature is not recorded in the original RHS.	**Inclusion of vernal pools in "Features of special interest" section.**
Banktop definition and determination	The extreme variation of flow regime can lead to difficulties in determining banktop and bankface. Often "two levels" of banktop can be identified, one for the high flow season and another for the low flow season.	Improved guidance on what clues to use in banktop determination (also in context with the survey season); **a new quality control item was included for surveyors to record the clues used to determine banktop.**
Land use	Different types of land use occur in Portugal and these are not entirely included in land use categories of the original RHS.	The definition of land use categories was adapted to include land use types occurring in Portugal.
Channel vegetation types	Examples of vegetation types in Portugal sometimes differ from those described in the original RHS.	Channel vegetation types description was adapted to include aquatic vegetation occurring in Portuguese rivers.
Notable nuisance plant species	Nuisance plant species occurring in Portugal differ from those occurring in the UK.	**Notable nuisance plant species section was adapted to include species occurring in Portugal. Channel nuisance plant species were also included.**

detect survey or input errors. The validation and adjustment of HQA and HMS indices to Portuguese rivers conditions is also planned. This task will use integrated data from previous projects (namely from 2003-2006 projects) and from WFD monitoring programmes.

FINAL REMARKS

The present paper describes the efforts to implement RHS methodology for fluvial hydromorphological characterization and quality assessment in Portugal in accordance with the WFD and a work plan defined by Portuguese Water Authorities to achieve this objective. The adaptations presented aim to improve RHS recording accuracy for hydromorphological assessment of Portuguese rivers and to overcome limitations regarding WFD requirements. Despite these changes, the guiding principle was to maintain the RHS philosophy and not to increase the method's complexity or time spent in surveys. At a larger time scale further work is needed to fully implement RHS, through nationwide surveyor training courses and development of a RHS database.

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