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Title Review on eco-hydromorphological methods

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Summary

Several ecological and hydromorphological assessment methods have been developed in different countries during the last years, with notable differences in terms of aims, scales, and approaches. In many cases, strengths and limitations of the different types of methods are not yet sufficiently known, although they are widely used in some European countries. The objective of this report is to provide an extensive overview on eco-hydromorphological assessment methods which are available for the implementation of the WFD, and to identify strengths, limitations, gaps, possible integration of different approaches, and needs for future progress.

The main emphasis is on 'hydromorphological assessment methods', i.e. methods and procedures developed and used to characterize hydromorphological conditions and classify the status of streams and rivers, including a review of indicators and parameters used within this context.

According to the EU Water Framework Directive (WFD) the assessment of stream hydromorphology requires the consideration of any modifications to flow regime, sediment transport, river morphology, and lateral channel mobility. To synthesize an overview of existing approaches for hydromorphological assessment and their applicability.

Starting from the beginning of 1980s, a large variety of assessment methods have been developed, with notable differences in their aims, spatial scales of application, approaches, reference conditions, etc. For this review, five broad categories of hydromorphological assessment methods have been distinguished: (1) Physical habitat assessment; (2) Riparian habitat assessment; (3) Morphological assessment; (4) Hydrological regime alteration assessment; (5) Longitudinal fish continuity assessment. Although a clear separation between different categories does not exist, this distinction enables the main characteristics and scope of each method to be clearly presented.

The first stage was to review the general characteristics of a total of 139 methods (European and non-European). For each of the five categories defined above, the main information concerning each method has been summarized, allowing for a comparative analysis of the methods. The second stage of the review focussed on a selection of European methods (in total 21), i.e. those methods that have been formally approved or that are commonly used (although without formal approval) by European countries for the implementation of the WFD. For each of these methods, the scope, characteristics, recorded features and indicators, processes and strengths have been summarized. Finally, a brief review of other tools and models used for a more detailed characterization, monitoring and analysis of physical habitats is presented.

Ecological assessment methods in use for determining the ecological status of European rivers were also reviewed. The review covers the methods that are being used by the EU countries to monitor ecological status. A total of 91 methods were considered, covering fish fauna, macrophytes, benthic diatoms, and benthic invertebrates from 27 European countries.

Based on the comprehensive review of existing methods, a series of strengths and limitations have been identified for each of the five categories of hydromorphological methods and then for the methods adopted by EU countries for the implementation of the WFD. From this analysis, the main gap identified in most existing and used methods is the insufficient consideration of physical processes in the assessment of hydromorphological conditions. With few exceptions, hydromorphological analysis adopted in most EU countries is limited to a physical habitat assessment, which is only one component of an overall hydromorphological evaluation. This is an important limitation because a characterization of physical habitats alone does not provide sufficient understanding of alterations or their causes and of pressure-responses (i.e. causes-effects), that are extremely important for the implementation of rehabilitation actions.

We recommend the development of a framework for integrated hydromorphological analysis, where the morphological and hydrological components are key parts of the evaluation and classification of hydromorphological state and quality, while physical habitat and longitudinal fish continuity should represent additional components that are useful for a complete characterization of hydromorphological conditions.

The review of existing ecological methods has also identified some additional limitation, particularly in their ability to respond to hydromorphological pressures. Methods using fish fauna, macrophytes, and benthic invertebrates are not pressure-specific; they will detect effects of multiple pressures, including hydromorphological pressures. Little information is available on the specific response of individual methods to hydromorphological pressures. Supplementary information characterising the pressures (hydromorphological and other) is required to identify problems and to plan appropriate measures.

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1. Introduction

The deliverable D1.1 "Review on eco-hydromorphological methods" derives from the activity carried out within the Task 1.1 "Existing ecological and hydromorphological methods".
It consists of a literature review of existing ecological and hydromorphological methods (indicators, tools and models) used in river management and restoration aiming to identify ecologically relevant physical structures on different spatial and temporal scales. To understand and predict eco-hydromorphological responses to man-made physical change.
The review is organized in 4 sections: 1. Introduction; 2. Review of existing hydromorphological methods; 3. Review of existing ecological methods; 4. Identification of strengths, limitations and gaps of existing methods and recommendations for future progress.
For Section 2 we collected more than 350 international bibliographic documents (i.e. journal papers, technical reports/guides, conference proceedings, book chapters, unpublished academic works, etc.). The review in Section 3 is largely based on the existing WISER compilation (http://www.wiser.eu/) complemented with information from the ECOSTAT intercalibration reports.

Several ecological and hydromorphological assessment methods have been developed in different countries, with notable differences in terms of aims, scales, indicators, collected data, and approaches. However, characteristics, differences, strengths, and limitations of the various methodologies are not always sufficiently clear, and this may represent a major gap for future monitoring of river conditions of European countries in the context of the WFD. This is particularly true for hydromorphology, which is a relatively new discipline introduced by the WFD and which needs to be included in the overall assessment of river conditions.
Starting from the beginning of 1980s, several methods and protocols for characterizing and evaluating physical stream conditions that can be defined as 'river habitat survey' or 'physical habitat assessment' were developed (e.g. Platts et al., 1983; Plafkin et al., 1989; Raven et al., 1997; Ladson et al., 1999; NERI, 1999; LAWA, 2000, 2002a, b), and some attempts have been made to standardize them (e.g. CEN, 2002; Parson et al., 2004). As a consequence of the availability of a wide variety of methods, this type of approach has been in most cases identified as the procedure for stream hydromorphological assessment required by the WFD.
Although the survey of physical habitat elements is useful for ecosystem characterization, the use of such methods for understanding physical processes and causes of river alterations is affected by a series of limitations (e.g. Fryirs et al., 2008; Entwistle et al., 2011). Fryirs et al. (2008) stated that a clear distinction should be made between a river audit (e.g. a physical habitat assessment) and a river condition assessment (e.g. the Australian River Condition Index; Healey et al. 2012). A 'physical habitat assessment' is essentially a data collection that generates information on presence and

frequency of physical habitats, while a 'river condition assessment' aims to measure both "pressure" and "response" variables (hydromorphological and biological indicators) and provides means to develop a clear understanding of pressure – response (i.e. cause – effect) relationships that regulate observed changes in system condition.

Recognition of the importance of geomorphic river conditions is reflected by an increasing effort to develop new methods based on a more sound geomorphological approach and with a stronger consideration of physical processes. The River Styles Framework (Brierley and Fryirs, 2005), the SYRAH-CE (Système Relationnel d'Audit de l'Hydromorphologie des Cours d'Eau; Chandesris et al., 2008), the IHG (Indice Hydrogeomorfologico; Ollero et al., 2007, 2011), and the MQI (Morphological Quality Index; Rinaldi et al., 2013) are examples of morphological assessment procedures that are based on a geomorphological approach.

As a consequence of the different approaches previously described, a wide variety of methods that can be classified as 'hydromorphological assessment' is now available. Notwithstanding various reviews on hydromorphological assessment methods are available (e.g. Raven et al., 2002; Fernandez et al., 2011; Weiss et al., 2008), there is still a need to better identify and understand what each method can or cannot achieve, how they could better integrate to cover possible gaps, and which are the areas that need further progress.

The **objective** of this report is therefore to provide an extensive overview on eco-hydromorphological assessment methods which are available for the implementation of the WFD, and to identify strengths, limitations, gaps, possible integration of different approaches, and needs for future progress.

The deliverable D1.1 "Review on eco-hydromorphological methods" derives from the activity carried out within the Task 1.1 "Existing ecological and hydromorphological methods". In this section we recall the planned activities of Task 1.1 (in italics), as reported in the REFORM DoW (Description of Work), and describe how these activities have been addressed in this deliverable. The overall content of D1.1 covers the general description of Task 1.1: *"A literature review of existing ecological and hydromorphological methods (indicators, tools and models) used in river management and restoration aiming to identify ecologically relevant physical structures on different spatial and temporal scales. To understand and predict eco-hydromorphological responses to man-made physical change."*

The main emphasis of the review is on 'hydromorphological assessment methods', i.e. methods and procedures developed and used to characterize hydromorphological conditions and classify the status of a stream, including a review of indicators and parameters used for this purpose. Ecological assessment methods in use for determining the ecological status of European rivers were also reviewed. The review on other existing tools and models is restricted to those used for a more detailed characterization, monitoring and analysis of physical habitats (as these have traditionally been the main focus of hydromorphology).

This implies a more restricted inventory and review of the methods previously mentioned as "… *tools and models*" in the DoW: in fact, other tools and models for an overall geomorphological and/or hydrological analysis have not been included in this report because this is a specific objective of WP2 and will be addressed there.

The structure of D1.1 reflects the list of topics reported in the program of activities of Task 1.1, described as follows. The review of existing methods is organized in two separate sections, the first one concerning hydromorphological methods (Section 2), and the second focussing on ecological methods (Section 3). These two sections together cover the first specific 'bullet point' of the DoW: *Review existing methods, including all steps from field survey to data evaluation, all variables and processes involved and perform a critical analysis of the suitability of available models.*

Based on the review and analysis of existing methods, an identification of strengths, limitations and gaps was carried out, followed by recommendations for future progress, in order to build the basis for improving or developing of new assessment methods. These issues are included in Section 4. Identification of limitations and gaps are reported in the first part of Section 4, concerning hydromorphological (sections 4.1 – 4.6) and ecological methods (section 4.7), respectively. This part covers the following two aspects ('bullet points') of the DoW:

- *To identify existing methods will be compared to current hydromorphological theories at varying spatial and temporal scales. To identify relevant, dynamic and potential parameters, processes, and data gaps.*
- *Review current metrics in use and add additional metrics if needed based on relevant bottlenecks for biota using results of current intercalibration works, ECOSTAT activities and analyses from Task 1.3.*

In the final part (section 4.8), we have summarized the needs and recommendations for future progress, which will be considered and further developed during the implementation of other WPs of REFORM (particularly in WP6), covering the final 'bullet point' of the DoW:

- *Develop a process-based eco-hydromorphological framework and select indicators to generate new survey methods or improve existing eco-hydromorphological ones (input to Task 6.2).*

2. Review of existing hydromorphological methods

The main emphasis of this review is on 'hydromorphological assessment methods', i.e. methods and procedures to characterize hydromorphological conditions and classify the status of a stream.
Hydromorphological assessment methods have been divided into 5 categories: (1) physical habitat assessment; (2) riparian habitat assessment; (3) morphological assessment; (4) hydrological regime assessment; (5) fish longitudinal continuity assessment. This distinction in categories allows comparison of methods which focus on similar aspects and are applied at comparable spatial scales (i.e. site, reach, catchment) and contexts (e.g. river channel, riparian areas, floodplain). A more detailed analysis of the methods used by European countries for the implementation of the WFD was also carried out. In total 139 methods (European and non-European countries) were reviewed. This is followed by a brief review of other existing tools and models that can be used for a more detailed characterization, monitoring and analysis of physical habitats.

According to the EU Water Framework Directive (WFD; European Commission, 2000) the assessment of stream hydromorphology requires the consideration of any modifications to flow regime, sediment transport, river morphology, and lateral channel mobility. The main emphasis of this review is on 'hydromorphological assessment', including various methods and procedures aimed at characterizing hydromorphological conditions and classifying the status of a stream.
The literature review of hydromorphological assessment methods starts from previously published reviews (e.g. Raven et al., 2002; McGinnity et al., 2005; Weiss et al., 2008), with a particular consideration of the recent state of the art reported by Fernandez et al. (2011). Then, for the purpose of this review, we collected more than 350 international bibliographic documents, consisting of journal papers, technical reports, technical guides, conference proceedings, book chapters, unpublished academic works (PhD and Masters theses), including power point presentations. All the analyzed documents have been uploaded and organized in Endnote libraries.
A wide variety of methods that can be classified as 'hydromorphological assessment' methods is available. While most of these previous reviews have included all methods in the broad category of 'physical habitat assessment' or 'river habitat characterization', for the present review we classified all hydromorphological assessment methods in a series of broad categories, which differ either according to the aim of the assessment (e.g. physical habitat, morphological or hydrological alterations, etc.) and/or the spatial context (e.g. channel vs. riparian zones) to which they are applied. This distinction is useful for a rapid identification of the main characteristics and scope of each method. However, it should be noted that a strict separation between different categories

is not feasible, and some overlaps exist, since some methods include indicators relevant to different categories. The spatial context and scale of each category is schematically reported in Figure 1, from which some overlaps relating to the investigated spatial context are evident.

The following broad categories of hydromorphological assessment methods were identified:

1. Physical habitat assessment. This category mainly includes methods to identify, survey and assess physical habitats.
2. Riparian habitat assessment. This category includes physical habitat assessment methods specifically developed for characterizing and assessing riparian habitats and vegetation.
3. Morphological assessment. This group includes methods performing a geomorphological evaluation rather than a physical habitat assessment, incorporating morphological characteristics and/or human pressures on hydromorphology.
4. Hydrological regime alteration assessment. This category includes methods that are specific to the assessment of hydrological regime alteration.
5. Longitudinal fish continuity assessment. This category includes methods that are specifically developed for the assessment of the longitudinal continuity for fish communities.

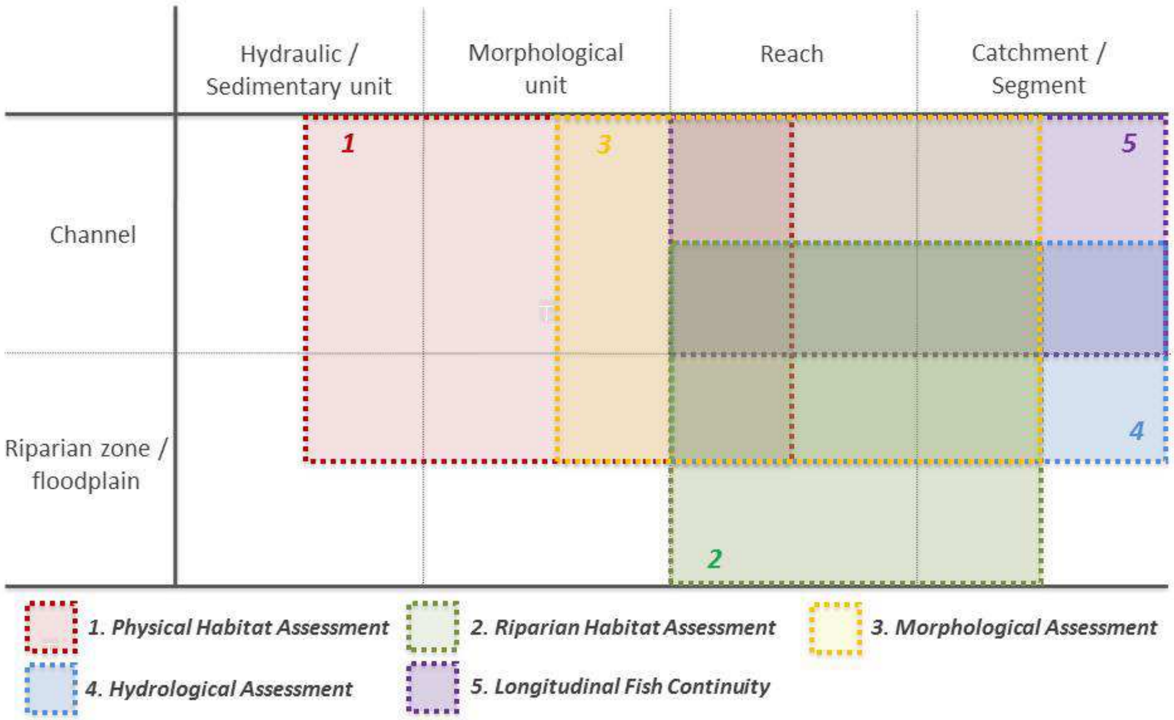

Figure 1 Spatial context, spatial scales and overlap between assessment method categories

Following previous reviews (e.g. Fernandez et al., 2011; Raven et al., 2002; Weiss et al., 2008), for each group of assessment methods a synthetic table was developed in which the row entries represent the categories of the main features as reported by the CEN (2002) standards. In the table we recorded whether the analyzed method considers or not a specific feature. Three options were considered: presence (✓), absence ( ), and probably assessed (PA), the latter indicating when there is an uncertainty concerning whether the feature is collected and/or when the feature may be indirectly obtained.

In general, the tables are structured to record 3 main categories of information:

1. General method characteristics (applied to the categories 1 to 5), which concerns information on data collection method/source, temporal and spatial scales, type of method (e.g. qualitative characterization or quantitative assessment by an index), and whether some reference conditions are used.
2. Recorded features (applied to the categories 1 to 5), which refer mainly to the CEN (2002) standards, i.e. the list of standard features which are recorded and assessed to evaluate the hydromorphological state of rivers (e.g. in the channel/banks and riparian area/floodplain).
3. River processes (applied to the categories 1 to 3), which indicates which methods also include considerations of river processes (lateral, longitudinal continuity; width and vertical adjustments).

Appendices A to C report a short definition of the table entries for each category of method.

In the analysis of each method, some information is provided on whether there are *reference conditions* against which the deviations of hydromorphological conditions are assessed.

The reference conditions approach is a well-established methodology for the assessment of freshwater ecosystems (e.g. Bailey et al., 2004). However, definition of a reference state for hydromorphology is problematic. In the last three decades, several studies have dealt with the issue of defining the geomorphic reference conditions of streams (e.g. Binder et al., 1983; Kern, 1992; Rhoads et al., 1999; Jungwirth et al., 2002, Palmer et al., 2005; Brierley and Fryirs, 2005; Dufour and Piégay, 2009). These studies show that there is still some debate on this topic and a common vision of reference conditions is lacking. Furthermore, a clear distinction should be made according to whether reference conditions are used to assess deviation from a natural condition and/or to define goals for river restoration.

A detailed review of the concept of reference conditions is not within the scope of this document. In brief, several approaches have been adopted or can be used for the definition of hydromorphological reference conditions, including:

(i) reference conditions based on empirical data obtained from reference sites;
(ii) reference conditions based on historic information (e.g. old maps);
(iii) modelled reference conditions (including conceptual models);
(iv) theoretical reference conditions taken in absence of any relevant alteration;
(v) reference conditions based on expert judgement;
(vi) reference conditions based on the historic range of variability and/or evolutionary sequence and ergodic reasoning (Brierley and Fryirs, 2005).

Across all categories, a total of 139 methods were reviewed: 73 from Europe, 46 from the US, 7 from Australia, 1 from Switzerland and 12 from other countries (Table 1).

Table 1 Summary of reviewed methods for each category. For methods (1): Netherlands (+1) means that they apply an additional method (the Austrian GEBD; Buhmann & Hutter, 1996); Austria (*) and Switzerland (+1) mean that RATyrol (BUWAL, 1998) is used in both countries. For methods (2): Spain (*) means that the QBR (Munné & Prat, 1998) is also applied in Greece. For methods (3): Ireland (+1) and Scotland (+1) mean that they additionally apply the English Stream Reconnaissance Handbook by Thorne (1998).

	(1) Physical habitat	(2) Riparian habitat	(3) Morphological assessment	(4) Hydrological assessment	(5) Fish continuity	TOT
Europe	**39**	**5**	**12**	**4**	**13**	**73**
Austria	6(*)				1	7
Belgium	2				2	4
Czech Republic	1		1			2
Denmark	5					5
England & Wales	4		4		2	10
France	3		2		2	7
Germany	5				1	6
Ireland (NI and RoI)	1		(+1)			2
Italy	2	1	1	1	1	6
Netherlands	1(+1)				1	3
Poland	3		1			4
Portugal	1					1
Scotland			1(+1)	1	1	4
Slovakia	1					1
Slovenia	1					1
Spain	2	4(*)	3	2	2	13
Sweden	2					2
US	**24**	**5**	**8**	**4**	**5**	**46**
Australia	**4**	**2**	**1**			**7**
Switzerland	**1(+1)**					**1**
Others*	**4**	**2**	**2**	**2**	**2**	**12**

*South Africa, Canada/Quebec, China, New Zealand, Taiwan, Ukraine

2.1 Physical habitat assessment

Physical habitat assessment methods aim to identify, survey and assess physical habitats and/or the overall functioning and conditions of rivers and streams. They are mainly applied at a local/reach scale, consider all the spatial components of a river corridor (channel, riparian area and floodplain), and assess the hydromorphological state at present time. We reviewed 72 methods belonging to this broad category (39 for European countries and 33 for non-European countries).

This category includes methods that are specific to identifying, surveying and assessing physical habitat conditions and overall river physical functioning.

This kind of approach is the most commonly used, given the importance of physical habitats in supporting ecosystem function. Several methods have been developed to characterize or assess physical habitats of rivers and streams worldwide (Mc Ginnity et al., 2005; Fernandez et al., 2011).

Table 2 and Table 3 summarise the key and the analyzed references for each assessment method. Definitions for table entries are given in Appendix A. Table 4 and Table 5 summarize the available information on physical habitat assessment methods for European and non-European countries respectively. In the following part of this section (as for the other 4 categories of assessment methods), we make a comparative analysis for each of the 3 categories of information (1. Method characteristics; 2. Recorded features; 3. River processes).

Table 2 Analyzed references for methods of physical habitat assessment, for European countries

Methods from European countries (Physical habitats)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Eco-morphological classification of channels according to WERTH	Werth	Austria	Werth (1987)	Mc Ginnity et al. (2005)
Ecological method for inventory and assessment of watercourse structures	WatercSt	Austria	Spiegler et al. (1989)	Mc Ginnity et al. (2005)
River structures: Recording – Assessing - Representing	GEBD (RSR)	Austria & Netherlands	Buhmann & Hutter (1996)	Mc Ginnity et al. (2005)
Assessment of river stretches with high or good habitat quality	AssRivSt	Austria	Muhar & Jungwirth (1998); Muhar et al. (2000)	Muhar et al. (2000); Mc Ginnity et al. (2005)
NÖMORPH	Nömorph	Austria	Freiland Umeltconsulting (2001a, b)	Mc Ginnity et al. (2005)
River´s Atlas Tyrol	RATyrol	Switzerland, Liechtenstein & Austria	BUWAL (1998)	Mc Ginnity et al. (2005)
Structural Evaluation of Watercourses	SEvalW	Belgium	Schneiders et al. (1993)	Mc Ginnity et al. (2005)
Structural and morphological river quality index	SK	Belgium	Wils et al. (1994)	Goethals & De Pauw (2001)
Ecohydromorphological river habitat assessment	EcoRivHab	Czech Republic	Matoušková (2006)	Weiss et al. (2008)
Quick assessment of the overall physical quality of streams as part of the DSFI sampling	DSFI	Denmark	Danish Environmental Protection Agency (1998)	Mc Ginnity et al. (2005)
Aarhus Index	Aarhus	Denmark	Kaarup (1999)	Mc Ginnity et al. (2005)
National Physical Habitat Index	NPHI	Denmark	NERI (1999)	Mc Ginnity et al. (2005)
Characterization of physical stream conditions within the Extended Biology Program	PhysSC	Denmark	Skriver et al. (1999)	Mc Ginnity et al. (2005)
Danish Habitat Quality Index	DHQI	Denmark	Pedersen et al. (2003)	NERI & SHMI (2004)
Mesohabitat Approach	MesoH	England	Tickner et al. (2000)	Original reference
Urban River Survey	URS		Davenport et al. (2004)	Original reference
River Habitat Survey	RHS	England & Wales	Raven et al. (1997)	Original reference
GeoRHS	GeoRHS	England	Environment Agency (2003)	Original reference
QUALPHY	Qualphy	France	Denortier & Goetghebeur (1996)	Mc Ginnity et al. (2005)
SEQ-Physique	SEQ-P	France	Agences de L´Eau (1998)	Mc Ginnity et al. (2005); Raven et al. (2002)
CARactérisation HYdromorphologique des Cours d'Eau	CARHYCE	France	ONEMA (2010)	Original reference
Stream Habitat Survey (LAWA-FS- SToM)	LAWA-FS-SToM	Germany	LAWA (2000)	Raven et al., (2002); Kamp et al. (2007); Sipek et al. (2010); Weiss et al. (2008); Lorenz (2011)

(Continued)

Stream Habitat Survey (LAWA-FS-MToL)	LAWA-FS-MToL	Germany	LAWA (2002a)	Kamp et al. (2007); Sipek et al. (2010); Weiss et al. (2008); Lorenz (2011)
Ecomorphological Survey of Large Rivers - Waterways	BfG - WW (ESLR)	Germany	Bundesanstalt für Gewässerkunde (2001)	Original reference; NERI & SHMI (2004); Kamp et al. (2007); Sipek et al. (2010)
LAWA-OS	LAWA-OS	Germany	LAWA (2002b)	Kamp et al. (2007); Sipek et al. (2010); Weiss et al. (2008)
German Structure Index	GSI	Germany	Feld (2004)	Original reference
River Hydromorphology Assessment Technique	RHAT	Northern Ireland & Rep. of Ireland	Murphy & Toland (2012)	Original reference
Index of Fluvial Functioning (IFF)	IFF	Italy	Siligardi et al. (2002)	Original reference
Core assessment of river habitat value and hydro-morphological conditions	CARAVAGGIO	Italy	Buffagni et al. (2005)	Original reference
Manual for hydromorphology	Handboek HYMO	Netherlands	Dam et al. (2007)	Original reference
River Hydromorphological Monitoring	MHR	Poland	lnicki et al. (2009)	Ilnicki et al. (2010)
Ecomorphological Evaluation of Watercourses	EcomorphEval	Poland	Ilnicki & Lewandowski (1997)	Grzybowski & Endler (2012)
Habitat Condition Index	HCI	Portugal	Oliveira & Cortes (2005)	Original reference
Hydromorphological Assessment Protocol for the Slovak Republic	HAP - SR	Slovakia	NERI & SHMI (2004); Lehotský & Grešková (2007)	Original reference
Methodology for assessing hydromorphological status	SIHM	Slovenia	Tavzes & Urbanic (2009)	Original reference
Index for the assessment of fluvial habitat in Mediterranean rivers	IHF (HIDRI - Protocolo2)	Spain	Pardo et al. (2002)	Original reference; Munné et al. (2006)
Protocolo para la valoración de la calidad hidromorfológica de los ríos - Protocol for the evaluation of the hydromorphological quality of rivers	HIDRI	Spain	Munné et al. (2006)	Original reference
Biotopkartering (Biotope mapping - Watercourses)	BiotopeMap	Sweden	Hallde'n et al. (2002)	Molin et al. (2010); Sandin (2009); SEPA (2007)
Riparian Channel Environmental Inventory	RCE	Sweden	Petersen (1992)	Original reference

Table 3 Analyzed references for methods of physical habitat assessment, for non-European countries

Method from non-European countries (Physical habitats)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
State of the Rivers Survey	SRS	Australia	Anderson (1993)	Mc Ginnity et al. (2005)
Index of Stream Condition	ISC	Australia	Ladson et al. (1999)	Original reference
Habitat Predictive Modelling	HPM	Australia	Davies et al. (2000)	Original reference
AusRivAS Physical Assessment Protocol	AusRivAs-PAP	Australia	Parsons et al. (2004)	Original reference; Mc Ginnity et al. (2005)
Urban Stream Morphology index	USM	China	Xia et al. (2010)	Original reference
Stream Habitat Assessment protocol	SHAP	NZ	Harding et al. (2009)	Original reference
Index of Habitat Integrity	IHI	South Africa	Kleynhans et al. (2008)	Original reference
Swiss modular concept	ModConc	Switzerland	Liechti et al. (1998)	Original reference; Bundi et al. (2000)
Ukrainian Field Survey	UA-FS	Ukraine	Scheifhacken et al. (2011)	Original reference
Methods for Evaluating Streams Conditions	MESC	US	Platts et al. (1983)	Original reference
Methods for Characterising Stream Habitat USGS	MCSH (NAWQA)	US	Fitzpatrick et al. (1998)	Mc Ginnity et al. (2005)
HABSCORE - US EPA Rapid Assessment Method	RBP	US	Plafkin et al. (1989); Barbour et al. (1999)	Barbour et al. (1999)
Rapid Stream Assessment Technique Field Methods	RSAT	US	Galli (1996)	Clean Water Services (2000); Somerville & Pruitt (2004)
Volunteer Stream Monitoring Method	VSMM	US	United States Environmental Protection Agency (1997)	Original reference; Mc Ginnity et al. (2005)
Rapid Habitat and Visual Stream Assessments (EMAP)	RHVSA-EMAP	US	Lazorchak et al. (1998)	USEPA (2004) (WSA)
Quantify Physical Habitat in wadeable stream (EMAP)	PHC (EMAP)	US	Kaufmann et al. (1999)	Original reference; Mc Ginnity et al. (2005)
Stream and Riparian Habitats Rapid Assessment Protocol	SRHRAP	US	Starr & McCandless (2001)	Somerville & Pruitt (2004)
Minnesota Habitat and Water Chemistry Protocol	MinHWCP	US	Minnesota Pollution Control Agency (MPCA) (2002)	Original reference
Montana Natural Heritage Wetland Assessment - GIS based	MNHWA	US	Crowe & Kudray (2003)	Original reference
Subjective Evaluation of Aquatic Habitats	SEvalAH	US	Kansas Dept. of Wildlife and Parks (KDWP) (2004)	Original reference
Wadeable Stream Assessment Field Ops	WSAss	US	USEPA (2004)	Original reference
Vermont Stream Geomorphic Assessment	VSGA	US	VANR (2004)	VANR (2010)
BURP	BURP	US	IDEQ (2004)	Original reference
NWHI	NWHI	US	Wilhelm et al. (2005)	Original reference
OHEPA Headwater Habitat Evaluation Index (HHEI)	HHEI	US	OHEPA (2002)	Kasich et al. (2012)
Qualitative Habitat Evaluation Index	QHEI	US	Rankin (1989)	Taft & Koncelik (2006)

(continued)

Fish and Fish Habitat Standard Inventory Procedure handbook	FFHSIP	US	Overton et al. (1997)	Original reference
Stream Visual Assessment Protocol	SVAP	US	USDA (2009)	Original reference
Stream Inventorying Handbook	SIH	US	US Forest Service (2006)	Original reference
Maryland Biological Stream Survey	MBSS	US	Stranko et al. (2010)	Original reference
Stream Corridor Survey - Stream Habitat	SCS-SH	US	MDEP (2009)	Original reference
Stream Corridor Assessment	SCA	US	Yetman (2001)	Original reference
Watershed Condition Evaluation	WCE	US	OWEB (2000)	Original reference

Table 4 Analyzed methods for physical habitat assessment for European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Methods from European countries (Physical habitats)		Werth	WatercSt	GEBD (RSR)	AssRivSt	Nömorph	RATyrol	SEvalW	SK	EcoRivHab	DSFI	Aarhus	NPHI	PhysSC	DHQI	MesoH	URS	RHS	GeoRHS	Qualphy	Seq-P	CarHyCE	LAWA-FS-SToM	LAWA-FS-MToL	LAWA-OS	BfG-WW (ESLR)	GSI	RHAT	IFF	Caravaggio	Handboek HYMO	MHR	EcomorphEval	HCI	HAP - SR	SIHM	IHF	HIDRI	BiotopeMap	RCE
1. METHOD CHARACTERISTICS																																								
A - SOURCE INFORMATION /DATA COLLECTION	Map/Remote sensing	✓	✓	✓	✓	✓		✓		✓					✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	PA		✓	PA		✓	✓	
	Field survey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Rapid field assessement	✓	PA			✓	✓	PA	PA		✓	✓	✓	✓	✓		✓	PA		✓	✓								✓	✓				✓		PA	✓			✓
	Modelling																														✓							✓	✓	
B - SPATIAL SCALE: LONG. SPATIAL SCALE	Fixed length									✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓			✓		✓	PA			✓		✓				✓
	Length vs width		✓																			✓							✓						✓					
	Variable length	✓		✓	✓	✓	✓	✓	PA	✓										✓	✓					✓	✓		✓		✓	✓	✓				✓	✓	✓	
B - SPATIAL SCALE: LAT. SPATIAL SCALE	Channel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Banks/Riparian zone	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
	Floodplain	✓	✓	✓	✓	PA	PA	✓		✓					✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
C - TEMPORAL SCALE	Present	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Recent														✓				PA	PA	PA				PA										PA					
	Historical																		PA						PA			✓			PA	PA			PA					
D - TYPE OF METHOD	Characteris./ Classification		PA	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	
	Assessment by index	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	General ass./Design																														✓					PA		✓		
E - REFERENCE CONDITIONS		✓	✓	✓	✓	✓			✓	✓					✓			✓	✓	✓	✓	PA	✓	✓	✓	PA	✓	✓	✓	✓	PA	✓	PA	✓	✓	✓	PA	✓	✓	

(Continued)		Werth	WatercSt	GEBD (RSR)	AssRivSt	Nömorph	RATyrol	SEvalW	SK	EcoRivHab	DSFI	Aarhus	NPHI	PhysSC	DHQI	MesoH	URS	RHS	GeoRHS	Qualphy	Seq-P	CarHyCE	LAWA-FS-SToM	LAWA-FS-MToL	LAWA-OS	BfG-WW (ESLR)	GSI	RHAT	IFF	Caravaggio	Handboek HYMO	MHR	EcomorphEval	HCI	HAP - SR	SIHM	IHF	HIDRI	BiotopeMap	RCE
2. RECORDED FEATURES																																								
A - CATCHMENT /VALLEY	Large scale characteristics		✓	✓	✓	✓		✓							✓			✓		✓	✓				✓	PA	✓	✓			✓	PA		PA	✓	✓		✓	✓	
	Hydro Regime /Discharge	✓	✓	✓	✓	✓				✓								✓	✓	✓	✓	✓	PA	PA	✓	✓	✓		PA	✓	✓	✓	✓		✓	✓		✓	✓	
	Valley form/features	✓	✓	✓	✓	✓				✓			✓		✓		PA	✓	✓	✓	✓		✓	PA	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓		
B - CHANNEL	Ch. pattern		PA		✓			✓	✓	✓					✓	PA		PA	✓	PA	PA		✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	PA		✓	✓	✓
	Channel forms	✓	✓	✓	✓	✓	PA	✓	✓	✓		✓	✓	✓	✓	PA	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	PA	PA	✓	✓	✓	✓	PA	✓
	Channel dimensions	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	PA
	Flow-type	✓	✓	✓	✓					✓			✓	✓	PA		✓	✓		✓	✓		✓	✓		PA		✓	PA	✓					✓	✓	✓	✓	PA	
	Substrate	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	PA	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	In-channel veg.		✓		✓					✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓				✓	✓	✓	✓	✓
	Woody debris				✓		PA			PA					✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓	PA	✓		✓	✓	✓	✓	✓	✓	✓
	Artificial features	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓		PA	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	
C - RIVER BANKS/ RIPARIAN ZONE	Bank profile/shape	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	PA	✓	✓	✓	✓	✓		✓		✓	PA	✓	✓	✓	✓		✓	✓		✓		
	Bank material	✓	✓	✓			✓										✓	✓	✓	✓	✓	✓	PA					✓	PA	✓						✓		PA		
	Riparian veg. structure	✓	✓	✓	✓		PA			✓		PA	✓	✓			✓	✓		✓	✓	✓	✓	✓		✓	PA	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓
	Longitudinal continuity veg.	✓	✓	✓	✓	✓				PA		✓	✓	✓			✓	✓	✓	✓	✓	✓			PA	✓	✓	✓	✓	✓		✓	PA	✓	✓	✓		PA		✓
	Riparian veg. width				✓		✓								✓		PA	PA	PA			✓				PA	✓	PA	✓	✓	PA		PA	PA		PA		PA		✓
	Artificial features	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
	Land use	✓	✓	✓	✓	✓	✓	✓					✓	✓			✓	✓	✓	✓	✓		PA	✓	✓		PA	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
D - FLOODPLAIN	Fluvial forms				✓					✓							✓	✓	✓	✓	✓		✓	PA	✓	✓	✓	✓		✓	PA	PA	✓		✓	✓		PA	PA	PA
	Land use		✓	✓	✓	PA	PA	✓		✓					✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

(Continued)	Werth	WatercSt	GEBD (RSR)	AssRivSt	Nömorph	RATyrol	SEvalW	SK	EcoRivHab	DSFI	Aarhus	NPHI	PhysSC	DHQI	MesoH	URS	RHS	GeoRHS	Qualphy	Seq-P	CarHyCE	LAWA-FS-SToM	LAWA-FS-MToL	LAWA-OS	BfG-WW (ESLR)	GSI	RHAT	IFF	Caravaggio	Handboek HYMO	MHR	EcomorphEval	HCI	HAP - SR	SIHM	IHF	HIDRI	BiotopeMap	RCE
3. RIVER PROCESSES																																							
A - LONGITUDINAL CONTINUITY	✓	✓	✓	✓	✓	✓	✓		✓		✓					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	PA	✓	✓		✓	✓	PA
B - LATERAL CONTINUITY			PA	✓					✓					PA		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	PA	✓	✓		PA	PA	✓
D - BANK EROSION / STABILITY				✓										✓		✓	✓	✓	PA	PA	PA	✓	✓	✓	✓	✓	✓	✓	✓	✓	PA			✓	✓		PA		✓
E - CHANNEL ADJUSTMENTS		PA																✓						PA	PA		✓			✓			PA	✓			PA		

Table 5 Analyzed methods for physical habitat assessment for non-European countries ("✓"= present; " "= absent; "pa"= probably assessed)

Methods from non-European countries

(Physical habitats)

		SRS	ISC	HPM	AusRivAs-PAP	USM	SHAP	IHI	ModConc	UA-FS	MESC	MCSH + BSI	RBP	RSAT	VSMM	RHVSA (EMAP)	PHC (EMAP)	SRHRAP	MinHWCP	MNHWA	SEvalAH	WSAss	VSGA	BURP	NWHI	HHEI	QHEI	FFHSIP	SVAP	SIH	MBSS	SCS-HS	SCA	WCE
1. METHOD CHARACTERISTICS																																		
A - SOURCE INFORMATION / DATA COLLECTION	Map/Remote sensing	✓	✓	✓	✓		✓	✓		PA	✓	✓	✓		✓					✓	✓		✓			✓		✓	✓	✓		✓	✓	✓
	Field survey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Rapid field assess.	✓	✓	✓	✓		PA		PA	PA			✓			✓	✓				PA				PA	✓	✓	PA	PA				PA	
	Modelling		✓	✓	✓	✓																												
B - SPATIAL SCALE: LONG. SPATIAL SCALE	Fixed length									✓				✓	✓				✓						✓	✓	✓				✓			
	Length vs width	✓			✓		✓					✓				✓	✓					✓		✓			PA		✓					
	Variable length		✓	✓		PA		✓	✓		✓		✓		✓			✓	✓		✓		✓					✓		✓		✓	✓	✓
B - SPATIAL SCALE: LAT. SPATIAL SCALE	Channel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Banks/Riparian zone	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Floodplain	✓	✓		✓	✓	✓	✓	PA	✓	✓		✓		✓		PA		PA	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
C - TEMPORAL SCALE	Present	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Recent				PA																	PA	PA									PA		✓
	Historical				PA															✓		PA	PA							✓		PA		✓
D - TYPE OF METHOD	Charact./Classification			✓	✓		✓		✓		✓	✓		✓		✓	✓	✓	✓			✓		✓		✓		✓		✓	✓	✓		✓
	Assessment by index	✓	✓			✓		✓		✓		✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓		✓		✓	✓		✓
	General ass./Design			PA	PA			PA															✓						PA				✓	
E - REFERENCE CONDITIONS		✓	✓	✓	✓	PA	✓	✓	✓	✓	PA		✓	PA	✓	PA				PA	✓	✓	✓	✓	PA	PA		PA	✓	PA		✓		✓

(Continued)		SRS	ISC	HPM	AusRivAs-PAP	USM	SHAP	IHI	ModConc	UA-FS	MESC	MCSH + BSI	RBP	RSAT	VSMM	RHVSA (EMAP)	PHC (EMAP)	SRHRAP	MinHWCP	MNHWA	SEvalAH	WSAss	VSGA	BURP	NWHI	HHEI	QHEI	FFHSIP	SVAP	SIH	MBSS	SCS-HS	SCA	WCE
2. RECORDED FEATURES																																		
A - CATCHMENT / VALLEY	Large scale characterization	✓	✓	✓	✓		✓	PA			✓	✓	✓		✓	✓				✓	✓		✓	✓		✓	PA	✓	✓	✓				✓
	Regime/Discharge	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓
	Valley form/features			✓	✓		✓		✓			✓						✓				PA	✓	✓				✓		✓		✓		✓
B - CHANNEL	Ch. pattern/planform	✓		PA	✓	✓	✓		✓	✓	✓		✓		PA		✓	✓	✓		✓	✓	✓	✓		✓	✓	PA	PA	✓		✓		✓
	Channel forms	✓	PA	✓	✓		✓	PA		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	PA	✓	✓	✓	✓	✓	✓	✓	
	Channel dimensions	PA	PA	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Flow-type	PA		✓	✓		✓			✓		PA	PA	✓	PA	✓	PA	PA									PA	PA			✓		PA	
	Substrate	PA		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	PA	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	In-channel veg.	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓			✓			✓				✓		✓	✓	✓	
	Woody debris	PA	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓		PA
	Artificial features	PA	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			PA	✓	✓	✓	✓	✓			PA	✓		✓	✓	✓	✓	✓	✓
C - RIVER BANKS/ RIPARIAN ZONE	Bank profile/shape	✓	PA	✓	✓	✓	✓		PA	✓	✓	✓	PA	PA	✓	✓	✓	✓	✓		PA	✓	✓	✓				✓	✓		PA	✓	✓	
	Bank material			✓	✓	✓			PA		✓	✓		✓	✓		PA	✓					✓											✓
	Riparian veg. structure	✓	✓	✓	✓		✓	✓	PA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓			PA		✓	✓	✓	✓	✓	✓	✓
	Long. continuity vegetation		✓		✓	✓	✓	✓	✓		PA	PA	✓	✓	✓		PA												✓		✓		✓	✓
	Riparian veg. width	✓	✓	✓	✓	✓	✓	✓	PA	PA		PA	✓	✓				✓	✓		PA	PA	✓	PA	✓	✓	✓		✓	✓	✓		✓	✓
	Artificial features	✓			✓	✓		✓	✓	✓	✓		✓		✓		✓			✓	✓	✓	✓			PA	✓		✓		✓	✓	✓	✓
	Land use	✓			✓	PA	✓	✓	PA		✓		✓	PA			✓	✓	✓	✓		✓	✓			✓	✓		✓		✓	✓	✓	✓
D - FLOODPLAIN	Fluvial forms		✓		PA	✓	PA	✓			PA							PA	PA	✓			✓		✓	PA	PA		✓	✓	PA		PA	✓
	Land use	✓			✓	✓	✓	✓	PA	✓	✓		✓		✓	✓	PA		PA	✓	✓		✓	✓		✓	✓		✓	PA	✓	✓	✓	✓
3. RIVER PROCESSES																																		
A - LONGITUDINAL CONTINUITY		✓	PA		✓	✓		✓	✓		PA									✓	PA		✓						✓	✓	PA	✓	✓	✓
B - LATERAL CONTINUITY			PA		✓	✓		✓	✓		✓		✓		✓				PA	✓	✓	✓	✓		PA				✓	✓			✓	✓
D - BANK EROSION / STABILITY		✓	✓	✓	✓	✓	✓	PA		✓	✓		✓	✓	✓			✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
E - CHANNEL ADJUSTMENTS			✓															✓				PA	✓						✓			✓	PA	

2.1.1 Method characteristics

Concerning the general characteristics of each method (Figure 2 and Figure 3), most physical habitat assessment methods collect information from field survey, and less than the half of them uses a rapid assessment protocol. This is true for both European and non-European countries. More than 50% of methods combine field analysis with data from maps and/or remote sensing (i.e. Desk study, Desktop protocol, etc.). However, maps and remote sensing techniques are mainly used to support a preliminary overview of the river and to help in reach identification rather than to enter directly in the assessment process. Non-European methods employ data from models a little more than European ones, even if this approach remains scarcely used. Models can sometimes be applied to support the definition of reference conditions (e.g. the Austrians GEBD, AssRivSt and Nömorph).

Concerning the longitudinal spatial scale of application, the assessment can be done by collecting data from fixed or variable reach lengths. Non-European methods apply the assessment mainly through the selection of variable reach lengths. The latter generally consists of a selection of homogenous reaches (based on large scale characteristics, e.g. geology and climate, and the presence of longitudinal discontinuities) or, in some cases, the assessment is carried out on the entire river length (e.g. MHR in Poland). A lower proportion of methods, both in Europe and outside, select the assessment reach by scaling the length in proportion to the channel width. Concerning the lateral spatial scale of application, 100% of physical habitat methods perform an analysis on the channel, while a slightly smaller proportion focus also on river banks and riparian areas, and less than 80% takes into consideration the surrounding floodplain. This is true both for European and non-European methods. This is obviously linked to the fact that the in-channel physical habitats are the main focus of the evaluation, and that physical habitat assessment methods are often used to support biological sampling (mainly macroinvertebrates).

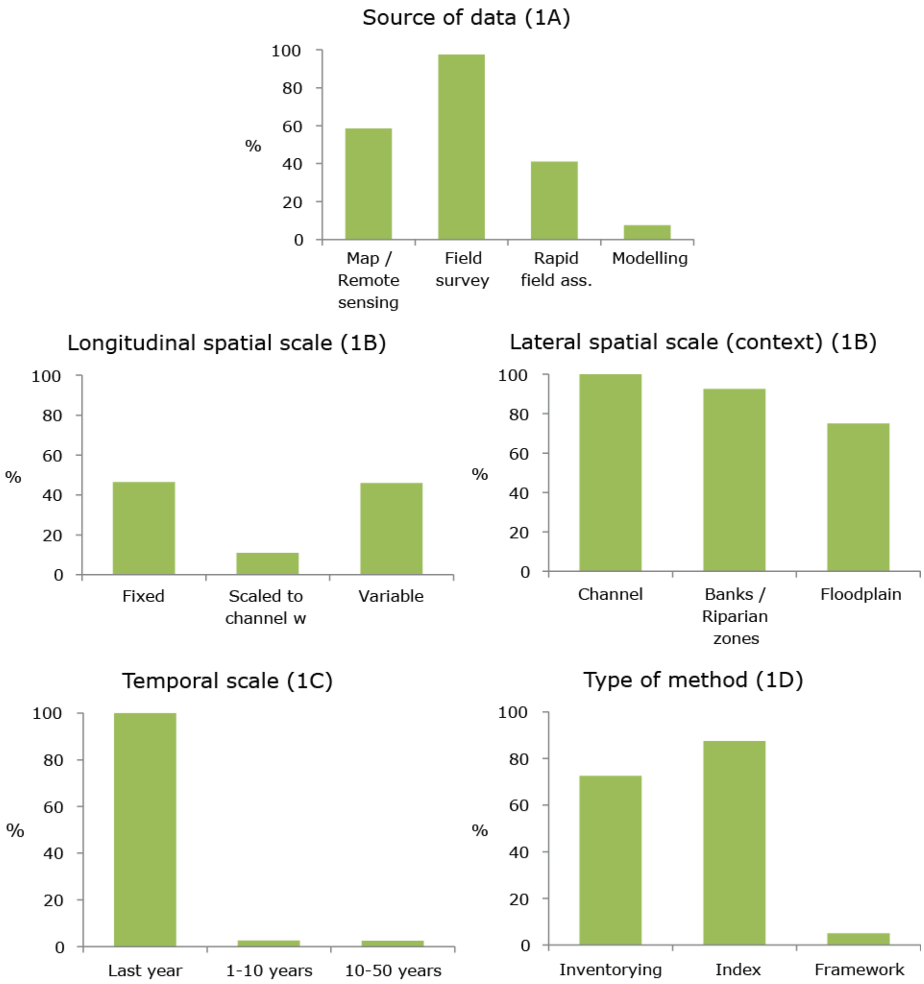

Figure 2 Synthesis of general information recorded by European methods for physical habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

Concerning the temporal scale, all methods focus on the assessment of the present river status, while a small proportion collect data that has the potential to be used for the assessment of recent and historical river conditions (e.g. GeoRHS). In some cases, historical conditions are used as reference conditions (e.g. the HAP in the Slovak Republic).

Generally, physical habitat assessment methods underpin estimation of one or more indices that provide a quantitative evaluation of the hydromorphological state of the stream (e.g. RHS, LAWA, etc.). Most methods classify physical quality status using a scoring system (some exceptions: the French CarHyCE, the physical component of the Danish DSFI). 72% of European methods (30% for non-European countries) make an inventory of features and at the same time aim to assess the river physical status or condition by calculating a final index. This category also includes methods aiming to evaluate the overall functioning of the stream (e.g. IFF in Italy, SEQ in France). Methods may also include some qualitative evaluation of ecological indicators (e.g. IFF includes

macroinvertebrates, vegetation, etc.) to provide an overall evaluation of stream conditions.
Reference conditions are explicitly taken into account by 64% of methods.

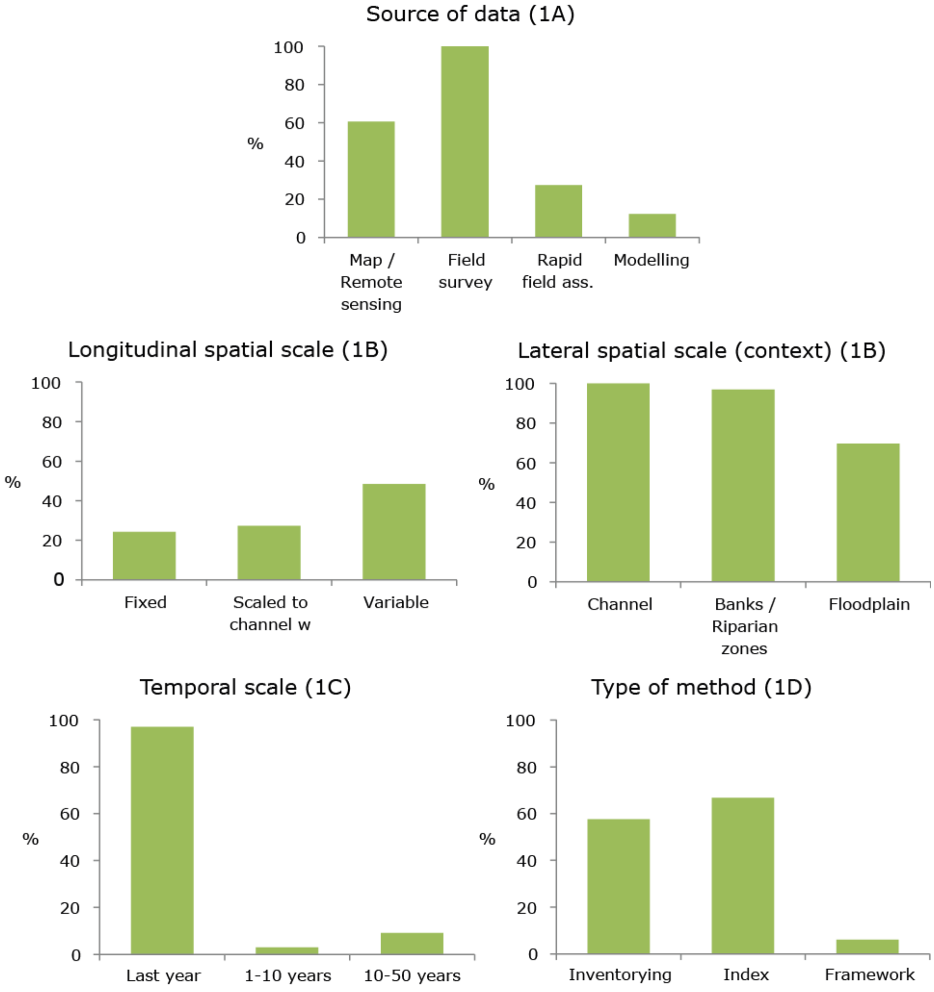

Figure 3 Synthesis of general information recorded by non-European methods for physical habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

2.1.2 Recorded features

Less than the half of European and 57% of non-European methods collect information on large scale catchment/valley characteristics (Figure 4 and Figure 5).
Physical habitat assessment methods generally use hydrological information only to characterize the hydrologic condition at the time of the survey (e.g. estimation of discharge). This is especially true in Europe, but in some cases (e.g. in Australia) the hydrological assessment is more detailed and meaningful, considering several properties of the river regime (e.g. Ladson et al., 1999; Parson et al., 2004). In addition, the IHI from South Africa, in its assessment of river perturbations (channel and riparian area) provides specific metrics for the assessment of hydrological alterations (Kleynhans et al., 2008). Some

assessment methods that do not incorporate hydrological measurements (e.g. RHS and adaptations), recommend that the assessment should be conducted under specific hydrological conditions such as during the early summer and during low flows.

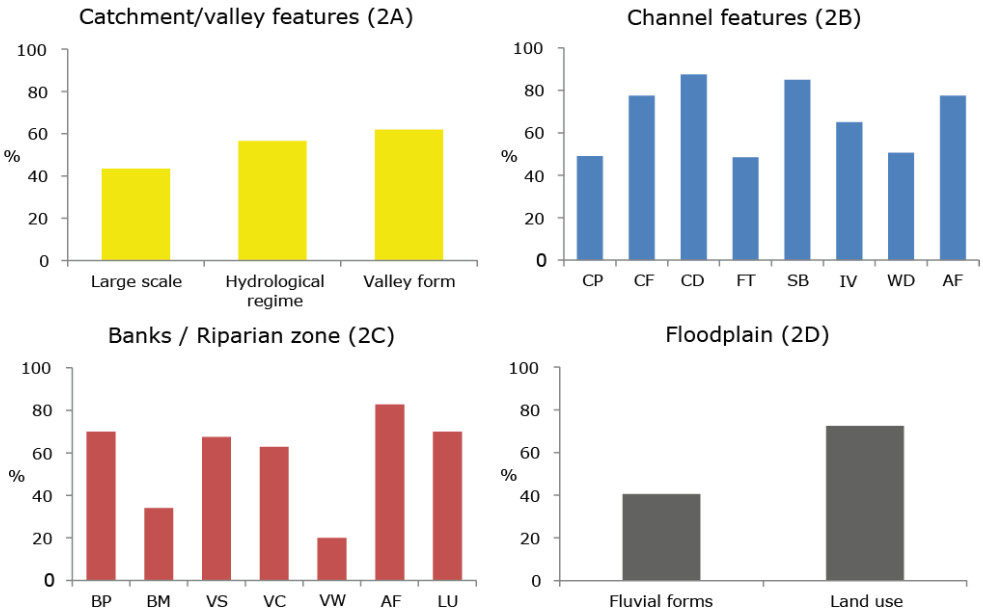

Figure 4 Features recorded by European methods for physical habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; AF, artificial features; LU, land use

In relation to channel features, European and non-European methods focus on almost the same types of characteristics (Figure 4 and Figure 5). Compared to non-European ones, European methods collect more information on flow types, whereas the former focus more on the presence of woody debris and the type of channel pattern and planform. Most methods (more than 81%) record channel dimensions, even though, in most cases, this is limited to a visual estimation of channel width. In contrast, few methods measure the extent of bed features (i.e. bars, islands, etc.), as is done in the Australian AusRivAs method. Methods rarely incorporate measurements of bank or floodplain widths. In terms of substrate characterization, most methods provide some information on sediment size and composition, while very few methods assess sediment substrate alterations such as channel armouring and clogging (or embeddedness) (e.g. the French CarHyCE, some US methods, the Australian AusRivAs). This can be explained by the difficulties of assessing substrate alteration. More than 72% of methods (both European and non-European) include in their assessment the evaluation of in-channel artificial features (i.e. dams, weirs, culverts, deflectors, etc.), which can potentially alter the presence and quality of physical habitats.

Concerning the banks and the riparian zone, European methods focus, more than non-European ones, on the presence of artificial features (e.g. bank protection, dykes, channelization, etc.) and land use. Non-European methods focus more on the degree of naturalness of riparian vegetation (e.g. structure, continuity, coverage).

Amongst the methods that collect floodplain features, only a small proportion (41% and 27% for European and non-European methods, respectively) record specific information on fluvial forms in the floodplain (e.g. presence of oxbow lakes and wetlands), while land use coverage is often assessed.

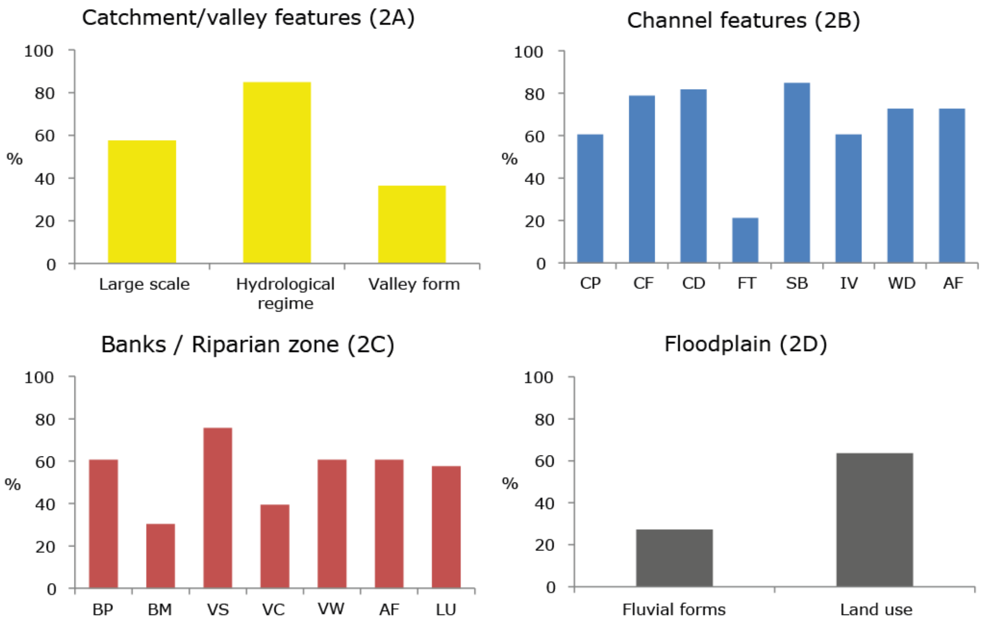

Figure 5 Features recorded by non-European methods for physical habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; AF, artificial features; LU, land use

2.1.3 River processes

European and non-European methods differ in the assessment of longitudinal continuity, which is evaluated in more than the 70% of European methods but less than the 40% of methods for non-European countries (Figure 6). This difference can be explained by the fact that most methods recently developed in Europe follow the CEN standards (2002).

Information on the presence of fluvial forms in the floodplain is useful for the assessment of the state of lateral hydraulic connectivity, which is assessed by almost the 50% of methods (51,3% for European methods, 45,5% for non-European methods).

European and non-European methods also differ in terms of bank erosion assessment, which are included in only 44% of European methods, but almost 80% of non-European methods. European physical habitat assessment methods collect mostly features related to bank profile and shape, indicators of the presence of potential habitats for biota (*refugia*), rather than information on bank stability. However the assessment of longitudinal, lateral and erosion processes can be obtained in part indirectly from the assessment and inventorying of natural and artificial features. On the other hand, a very small proportion of methods, both in Europe (10%) and outside (15%), take account of processes related to channel adjustments (widening/narrowing, aggradation/degradation).

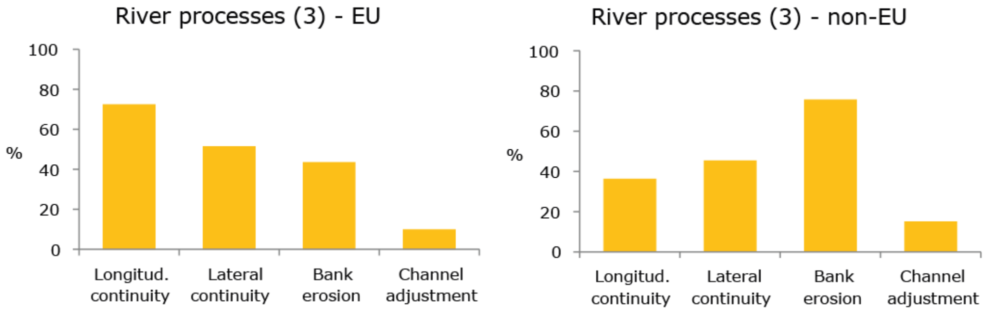

Figure 6 Information on river processes considered by European (on the left) and non-European (on the right) methods for the physical habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

2.2 Riparian habitat assessment

Riparian habitat assessment methods aim to identify, survey and assess riparian habitat conditions of rivers and streams. They are mainly applied at a local/reach scale, and generally to the overall river corridor, but focussing on vegetation characteristics. We reviewed 14 methods in total (5 for European countries and 9 for non-European countries).

This category includes methods developed with a specific aim of characterizing and assessing riparian habitats and vegetation (e.g. QBR and RQI in Spain). However, the analysis is not strictly limited to riparian habitats and vegetation, as some of the indicators that are used can be also included in other categories.

Riparian systems have been considered to be an integral component of riverine systems for several decades (González Del Tánago & García De Jalón, 2006), but the development of specific methods devoted to assessing riparian ecosystem conditions are a relatively recent practice, at least in Europe (e.g. Munné & Prat, 1998). In the USA, riparian assessment is often coupled with the assessment of wetland ecosystem functioning (e.g. PFC, Prichard et al., 1998); furthermore a large body of literature exists on methods focusing specifically on wetlands (e.g. HGM, Smith et al., 2001).

Table 6 and Table 7 summarize the key and analyzed references for each assessment method. Definitions for table entries are given in Appendix A. Table 8 and Table 9 synthesize the information on riparian habitat assessment methods for European and non-European countries, respectively.

Table 6 Analyzed references for methods of riparian habitat assessment for European countries

Method from European countries (Riparian habitats)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Buffer Strip Index and Wild State Index	BSI & WSI	Italy	Braioni & Penna (1998)	Original reference
Índice de vegetación de ribera/ Qualitat del Bosc de Ribera - Riparian Forest Quality Index (Protocolo HIDRI n.7)	QBR	Spain, Greece	Munné & Prat (1998)	Munné et al. (2003)
Índice de Vegetación Fluvial (Protocolo HIDRI n.8)	IVF (HIDRI)	Spain	Munné et al. (2006)	Original reference
Riparian Forest Evaluation (RFV)	RFV	Spain	Magdaleno et al. (2010)	Original reference
Riparian Quality Index	RQI	Spain	González Del Tánago & García De Jalón (2011)	Original reference

Table 7 Analyzed references for methods of riparian habitat assessment for non-European countries

Method from non-European countries (Riparian habitats)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Tropic Rapid Appraisal of Riparian Conditions	TRARC	Australia	Dixon et al. (2005)	Original reference
Rapid Appraisal of Riparian Conditions	RARC	Australia	Jansen et al. (2005)	Original reference
Indice de Qualité de la Bande Riveraine	IQBR	Quebec	Saint-Jacques & Richard (1998)	Original reference
Riparian Vegetation Response Assessment Index	VEGRAI	South Africa	Kleynhans (2007)	Original reference
Proper Functioning Condition	PFC	US	Prichard et al. (1998)	Original reference
Hydrogeomorphic approach to assessing wetland functions	HGM	US	Smith et al. (1995)	Original reference
Visual Assessment of Riparian Health	VARH	US	Ward et al. (2003)	Original reference
Monitoring Vegetation Resources in Riparian Areas	VRRA	US	Winward (2000)	Original reference
Riparian/Wetlands Assessment	RWA	US	OWEB (2000)	Original reference

Table 8 Analyzed methods for riparian habitat assessment for European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Methods from European countries (Riparian habitats)			BSI & WSI	QBR	IVF (HIDRI)	RFV	RQI
1. METHOD CHARACTERISTICS							
A - SOURCE OF INFORMATION / DATA COLLECTION		Map/Remote sensing	✓	PA	PA	PA	PA
		Field survey	✓	✓	✓	✓	✓
		Rapid field assessment	✓	PA		✓	PA
		Modelling					
B - SPATIAL SCALE	LONG. SPATIAL SCALE	Fixed length	✓		✓		
		Length vs width				✓	
		Variable length		✓		✓	✓
	LATERAL SPATIAL SCALE	Channel	✓	✓	✓	✓	✓
		Banks/Riparian zones	✓	✓	✓	✓	✓
		Floodplain	✓	✓	✓		✓
C - TEMPORAL SCALE		Present	✓	✓	✓	✓	✓
		Recent		PA	PA	PA	PA
		Historical		PA			PA
D - TYPE OF METHOD		Characterization/Classification	✓		✓		PA
		Assessment by index	✓	✓	✓	✓	✓
		General assessment/Design					PA
E - REFERENCE CONDITIONS				PA	PA		✓
2. RECORDED FEATURES							
A - CATCHMENT / VALLEY		Large scale characteristics	✓				✓
		Hydrological regime/Discharge	✓		PA	PA	✓
		Valley form/features					✓
B - CHANNEL		Channel pattern/planform	✓				PA
		Channel forms	✓	✓	PA		PA
		Channel dimensions	✓		✓	✓	✓
		Flow-type					
		Substrate	✓	✓	PA		
		In-channel vegetation	✓		✓		
		Woody debris					✓
		Artificial features/structures	✓	✓			
C - RIVER BANKS/ RIPARIAN ZONE		Bank profile/shape	✓	✓	✓		✓
		Bank material	✓	✓	PA		✓
		Riparian veg. structure	✓	✓	✓	✓	✓
		Long. continuity riparian veg.	✓	✓	✓	✓	✓
		Riparian vegetation width	✓	PA	✓	PA	✓
		Natural/Exotic species	✓	✓	✓	✓	✓
		Species distribution/coverage	✓	✓	✓	✓	✓
		Vegetation regeneration			PA	✓	✓
		Riparian soil					✓
		Artificial features/structures	✓	✓	✓	PA	✓
		Land use	✓	✓	✓	PA	✓
D - FLOODPLAIN		Fluvial forms					PA
		Land use	✓	✓	✓		✓
3. RIVER PROCESSES							
A - LONGITUDINAL CONTINUITY			PA	PA		PA	PA
B - LATERAL CONTINUITY			PA	PA	PA	PA	✓
D - BANK EROSION / STABILITY					PA		✓
E - CHANNEL ADJUSTMENTS							✓

Table 9 Analyzed methods for riparian habitat assessment for non-European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Methods from non-European countries (Riparian habitats)			TRARC	RARC	IQBR	VEGRAI	PFC	HGM	VARH	VRRA	RWA
1. METHOD CHARACTERISTICS											
A - SOURCE INFORMATION/ DATA COLLECTION		Map/Remote sensing			✓		PA	✓			✓
		Field survey	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Rapid field assess.	✓	✓							
		Modelling									
B - SPATIAL SCALE	LONG. SPATIAL SCALE	Fixed length	✓	PA	✓					✓	
		Length vs width									
		Variable length		✓		✓	PA	✓	PA	✓	✓
	LATERAL SPATIAL SCALE	Channel				✓	✓		✓		
		Banks/Riparian zones	✓	✓	✓	✓	✓		✓	✓	✓
		Floodplain				✓		✓	✓	PA	✓
C - TEMPORAL SCALE		Present	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Recent									
		Historical					PA				
D - TYPE OF METHOD		Characterization/Classification					✓			✓	✓
		Assessment by index	✓	✓	✓	✓			✓	PA	
		General assess./Design					PA	PA			
E - REFERENCE CONDITIONS						✓	PA	✓		✓	✓
2. RECORDED FEATURES											
A - CATCHMENT / VALLEY		Large scale characteristics					PA				
		Hydrological regime/Discharge				PA	✓	✓			
		Valley form/features									
B - CHANNEL		Channel pattern/planform					✓				
		Channel forms					✓		✓		
		Channel dimensions					✓				
		Flow-type							✓		
		Substrate					PA		✓		
		In-channel vegetation							✓		
		Woody debris	PA	PA			✓		✓		PA
		Artificial features/structure				✓	✓				
C - RIVER BANKS/ RIPARIAN ZONE		Bank profile/shape									
		Bank material								PA	
		Riparian vegetation structure	✓	✓	✓	✓	✓		✓	✓	✓
		Long. continuity vegetation	✓	✓	PA	PA	PA		✓	PA	✓
		Riparian vegetation width	✓	✓		PA			✓		✓
		Natural/Exotic species	✓	✓	✓	✓				✓	
		Sp. distribution/coverage	✓	✓	✓	✓	✓		PA	✓	
		Vegetation regeneration	✓	✓		✓	✓		✓	✓	✓
		Riparian soil			✓		✓			PA	
		Artificial features/structure	PA		✓	✓	✓				
		Land use			✓	✓			✓	PA	✓
D - FLOODPLAIN		Fluvial forms						✓			✓
		Land use				✓			✓	PA	
3. RIVER PROCESSES											
A - LONGITUDINAL CONTINUITY						PA	✓				
B - LATERAL CONTINUITY				PA	PA	PA	✓	✓	✓	PA	✓
D - BANK EROSION / STABILITY			PA		PA		✓		✓	✓	
E - CHANNEL ADJUSTMENTS							PA			PA	

2.2.1 Method characteristics

All European and non-European methods for the assessment of riparian conditions make use of field assessment protocols. European methods often comprise rapid field assessment protocols. The support of maps and remote sensing techniques remains limited, while no methods make use of data derived from modelling techniques (Figure 7 and Figure 8). In general, European methods aim to assess the general conditions of riparian habitats (using index/quality classes); some methods (i.e. BSI & WSI, IVF) also make an inventory of features, which often correspond with the sampling of vegetation community composition (Figure 7).
It is a little different outside Europe, where methods make an inventory or use an index, even if qualitative assessments still prevail (more than 50%; Figure 8).

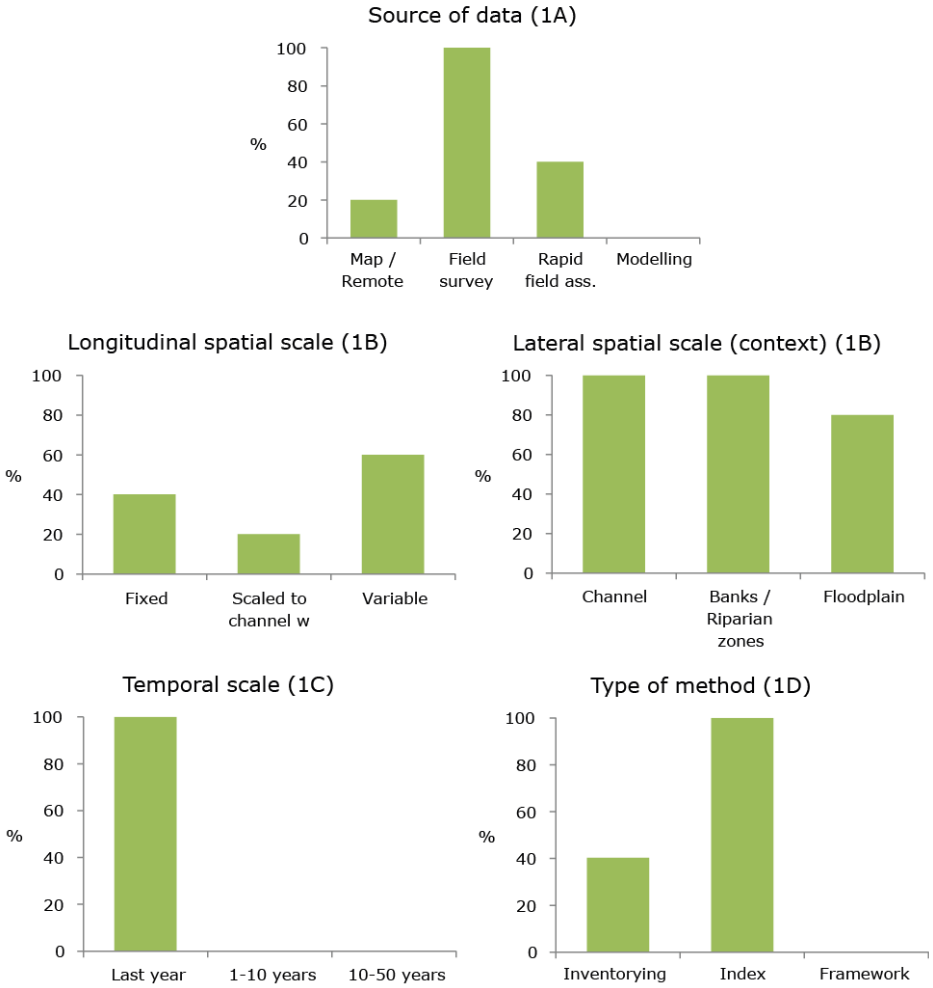

Figure 7 Synthesis of general information recorded by European methods for riparian habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

The HGM (Smith et al., 2001) is reported as an example of methods developed for the assessment of wetlands (Table 9).

Concerning the spatial scales of application, assessment of riparian habitats mainly focuses on the reach scale, that is in an area of homogenous vegetation characteristics (variable reach lengths). Some methods define, a priori, the size of the river reach to be assessed (e.g. 100m x 100m in the Italian BSI&WSI). The Spanish RFV is the only example in which reach length is scaled to channel width; this method is more geomorphologically-based in comparison with others. European methods have a broader ecosystem application (channel, banks and floodplain) compared to non-European ones. In fact, the latter collect information that is mainly limited to the riparian zone and the floodplain (Figure 7 and Figure 8).

In relation to the temporal scale, all of the investigated methods aim to characterize and/or assess the state of riparian habitats in their present condition, i.e. at the time of the survey.

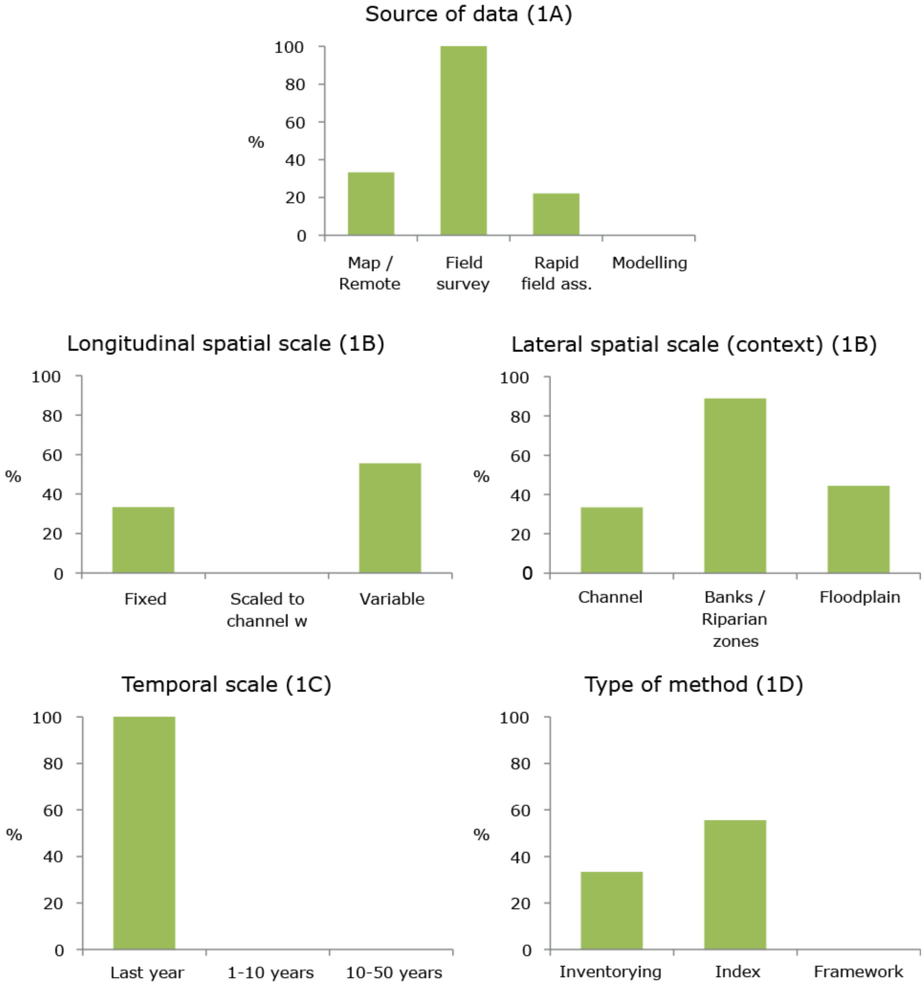

Figure 8 Synthesis of general information recorded by non-European methods for riparian habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

Amongst the European methods, only the RQI (González Del Tánago & García De Jalón, 2011) refers directly to reference conditions, where they are theoretically defined. Concerning the analyzed methods applied outside Europe, almost 50% relate the riparian quality to reference conditions.

2.2.2 Recorded features

These methods rarely include large scale characteristics, such as valley features or properties of the hydrological regime (Table 9, Figure 9). For channel features, European methods record mainly channel dimensions, even if not directly (80%; e.g. to compare the width of the vegetated area to channel width). These methods are developed in Mediterranean areas (Italy and Spain) where it is common to observe a multi-channel pattern, and where channel forms (i.e. island, bars) are frequently vegetated and so are included in the assessment of riparian habitats (CF = 40%; Figure 9). In contrast to non-European methods, European ones do not include the assessment of in-channel habitats (i.e. flow types); indeed, only the RQI takes into account the presence of woody debris (Figure 9 and Figure 10). European methods assess the structural features of banks (e.g. profile, shape, artificial features) in more detail, whereas non-European ones focus mainly on the vegetation characteristics and on the land use of banks and riparian areas.

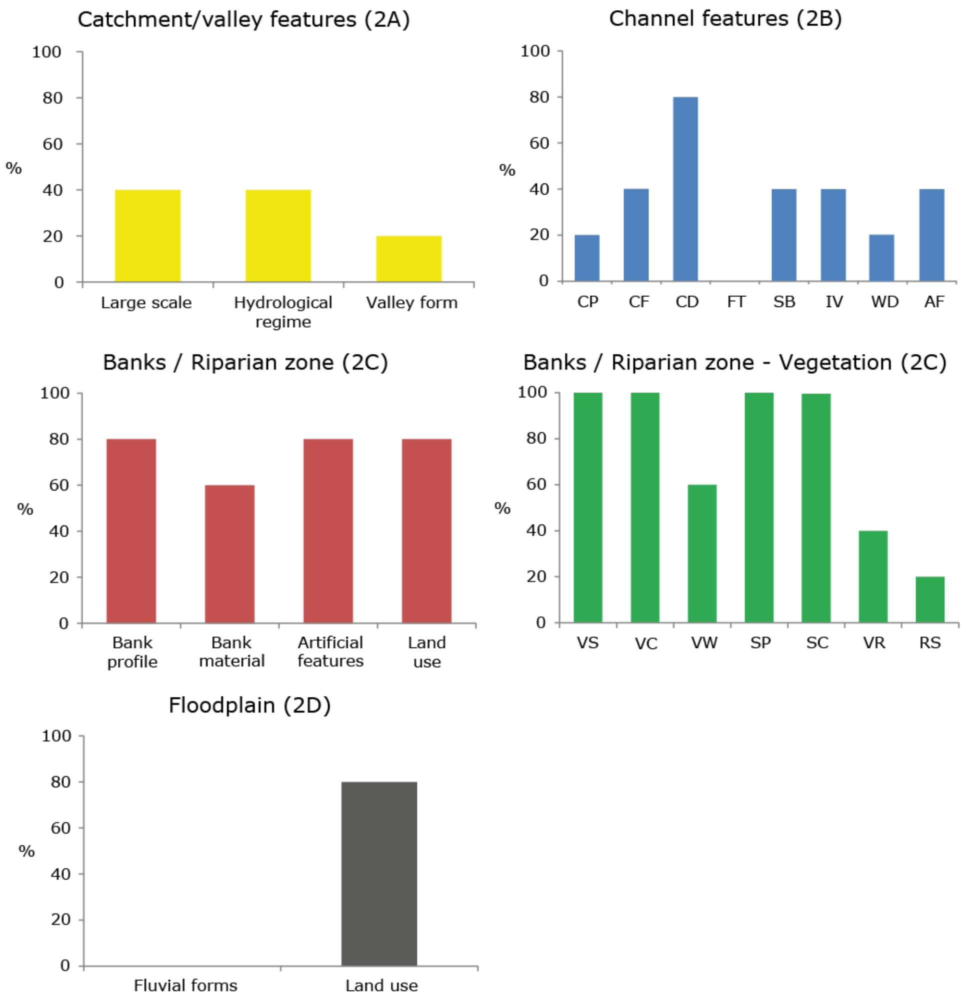

Figure 9 Features recorded by European methods for riparian habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; AF, artificial features; LU, land use. Vegetation features: VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; SP, specie composition; SC, species coverage; VR, vegetation regeneration; RS, riparian soil

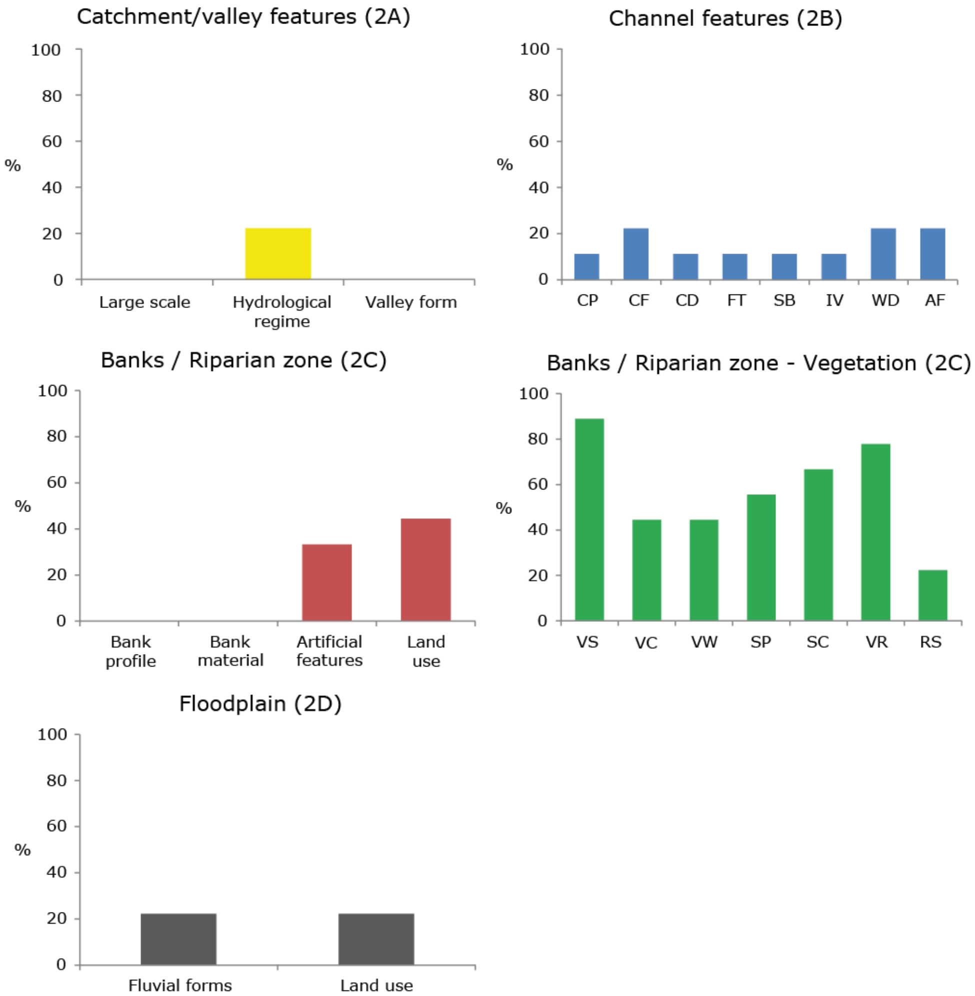

Figure 10 Features recorded by non-European methods for riparian habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; AF, artificial features; LU, land use. Vegetation features: VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; SP, specie composition; SC, species coverages; VR, vegetation regeneration; RS, riparian soil

The vegetation features most commonly assessed by European methods are the vegetation structure, longitudinal continuity, species composition and coverage. A special emphasis is placed on the presence of exotic species and their abundance compared to those of autochthonous ones (i.e. species composition and coverage). The width of the riparian vegetation buffer along a river is also taken into account, given that it may support the quality of lateral riparian habitat continuity, and connectivity with its floodplain (floodplain land use, 80% of methods). In the evaluation of riparian habitat quality, non-European methods assign greater importance to the temporal dynamics of vegetation pattern (regeneration, 77,8%).

2.2.3 River processes

Only a small proportion of methods attempt to relate the assessment to river processes (Figure 11).

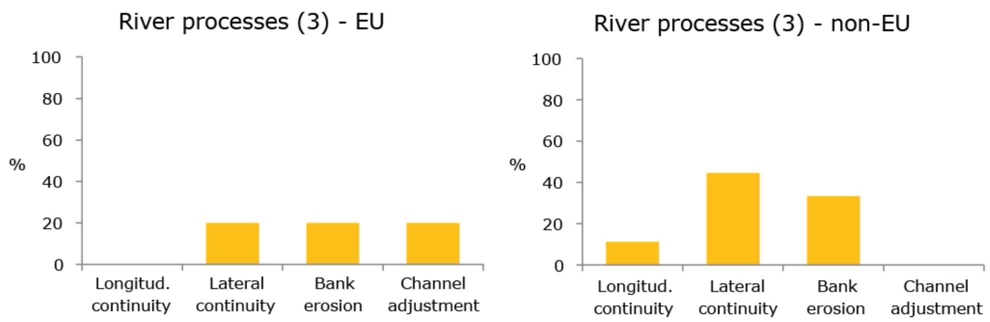

Figure 11 Information on river processes considered by European (on the left) and non-European (on the right) methods for the riparian habitat assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

2.3 Morphological assessment

Methods for morphological assessment differ from physical habitat assessment methods as they have a broader geomorphological perspective, and give a greater consideration to physical processes (e.g. hydrological and sediment continuity, sediment transport, erosion, channel adjustments) and alterations derived from human pressures. They are generally applied at the reach and catchment scales. They are process-oriented and also generally evaluate the river hydromorphological conditions at a greater temporal scale. We reviewed 23 methods in total (12 for European countries and 11 for non-European countries).

This category includes methods with a broader geomorphological perspective, that take account of morphological characteristics, physical processes and/or human pressures on hydromorphology. They are not necessarily aimed at acquiring an index (with some exception, e.g. the IHG in Spain, Ollero et al., 2007), as they can include methodological frameworks (e.g. River Styles Framework, Brierley and Fryirs, 2005), general procedures aimed to characterize human pressures (e.g. SYRAH-CE in France, Chandesris et al., 2008), or methodologies aimed towards the design of river restoration interventions (e.g. Natural Channel Design by Rosgen, 1996).

Table 10 and Table 11 summarise the key and analyzed references for each assessment method. Definitions for table entries are given in Appendix A. Table 12 and Table 13 synthesise the information on morphological assessment methods for European and non-European countries respectively.

Table 10 Analyzed references for methods of morphological assessment for European countries

Method from European countries (Morphological assessment)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Hydroecological Monitoring method	HEM	Czech Republic	Langhammer (2007)	Langhammer (2009); Matouskova et al. (2010)
Fluvial Audit	FA	England	Environment Agency (1998)	Branson (2005); Sear et al. (2008)
Stream Reconaissance Handbook	SRH	England, Scotland, Wales and Northern Ireland	Thorne (1998)	Original reference
Geomorphological Assessment Process	GAP	England	Sear et al. (2008)	Original reference
Technical Assessment Method - Risk of Mrophological Alteration	TAM - MorphoAlter	England	EA Technical Assessment Method, Hydromorphology Project	Original reference
Systeme Relationnel d'Audit de l'Hydromorphologie des Cours d'Eau	SYRAH-CE	France	Chandesris et al. (2008)	Original reference
Protocole AURAH-CE AUdit RApide de l'Hydromorphologie des Cours d'Eau	AURAH-CE	France	Valette et al. (2010)	Original reference
Morphological Quality Index (Indice di Qualità Morfologica)	MQI	Italy	Rinaldi et al. (2013)	Original reference
Methodology for the Assessment of River Hydromorphological Quality	RHQ	Poland	Wyzga et al. (2009)	Original reference; Wyzga et al. (2009, 2012)
Morphological Impact Assessment Method	MImAS	Scotland	UKTAG (2008)	Original reference; SEPA (2006)
Índice hidrogeomorfológico - Hydro-Geomorphologic Index	IHG	Spain	Ollero et al. (2007)	Original reference; Ollero et al. (2011)
HIDRI - Protocolo 1: Parametros de caracterizacion morfologica	HIDRI – Protocolo 1	Spain	Munné et al. (2006)	Original reference

Table 11 Analyzed references for methods of morphological assessment for non-European countries

Method from European countries (Morphological assessment)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
River Styles Framework	RSF	Australia	Brierley & Fryirs (2005)	Brierley & Fryirs (2000); Fryirs (2003)
Geomorphological Index (River Health Programme Index)	GI	South Africa	Rowntree & Wadeson (2000)	Original reference; Rowntree & Ziervogel (1999)
Geomorphological driver Assessment Index	GAI	South Africa	Kleynhans et al. (2005)	Original reference; du Preez & Rowntree (2006)
Natural Channel Design	NCD	US	Rosgen (1996)	Rosgen (2006)
Watershed Assessment of River Stability and Sediment Supply	WARSSS	US	Rosgen (2006)	Original reference
Channel evolution models	CEM	US	Schumm et al. (1984); Simon & Hupp (1986)	Darby and Simon (1999); Simon et al. (2007)
Rapid Geomorphic Assessment	RGA	US	Moe (1999); Simon & Downs (1995)	CLOC (2011); Heeren et al. (2012); VANR (2010)
Stream Corridor Survey - Rapid Geomorphic Assessment	SCS-RGA	US	MDEP (2009)	Original reference
Stream channel reference site	SCRS	US	Harrelson et al. (1994)	Original reference; McGinnity et al. (2005)
Channel Modification Assessment	CMA	US	OWEB (2000)	Original reference
Stream Assessment Protocol	SAP	US	Starr (2009)	Original reference

Table 12 Analyzed methods for morphological assessment for European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from European countries (Morphological assessment)		HEM	FA	SRH	GAP	TAM	SYRAH-CE	AURAH-CE	MQI	RHQ	MImAS	IHG	HIDRI (P1)
1. METHOD CHARACTERISTICS													
A - SOURCE INFORMATION/ DATA COLLECTION	Map/Remote sensing	✓	✓	PA		✓	✓	✓	✓	✓	✓	✓	✓
	Field survey	✓	✓	✓				✓	✓	✓	✓	✓	✓
	Rapid field assess.							PA					
	Modelling				✓								
B - SPATIAL SCALE – LONG. SPATIAL SCALE	Fixed length									✓	✓		
	Length vs width	✓		✓				✓					
	Variable length	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓
B - SPATIAL SCALE – LATERAL SPATIAL SCALE	Channel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Banks/Riparian zones	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Floodplain	✓	✓	✓	✓	✓	✓	✓	✓	✓	PA	✓	✓
C - TEMPORAL SCALE	Present	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Recent			PA		PA			✓	✓	PA	✓	
	Historical	✓	✓	PA	✓	PA			✓	✓	PA	PA	
D - TYPE OF METHOD	Characterization/classif.	✓	✓	✓			✓	✓					✓
	Assessment by index	✓			✓	✓			✓	✓	✓	✓	
	General assess./Design		✓	✓	✓	✓	✓				✓		
E - REFERENCE CONDITIONS		✓	✓		✓				✓	✓		✓	
2. RECORDED FEATURES													
A - CATCHMENT / VALLEY	Large scale charact.		✓	✓	✓	✓	✓		✓			✓	
	Hydrological regime/Discharge	✓	✓	✓	✓	✓	✓		✓	✓		✓	
	Valley form/features		✓	✓	✓		✓		✓				✓
B - CHANNEL	Ch. pattern/planform	✓	✓	✓	✓		PA		✓	✓	✓	✓	✓
	Channel forms	✓	✓	✓	✓			✓	✓	✓	✓	✓	PA
	Channel dimensions	✓	✓	✓	✓		PA	✓	✓	✓	PA	✓	✓
	Flow-type		✓	✓	✓						PA		
	Substrate	✓	✓	✓	✓			✓	✓	✓	✓	✓	
	Physical parameters		✓		✓							✓	
	In-channel vegetation		✓		✓					✓	✓		
	Woody debris	✓	✓		✓				✓	✓	✓		
	Artificial features/structures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
C - RIVER BANKS/ RIPARIAN ZONE	Bank profile/shape	✓	✓	✓	✓				✓	✓	✓	✓	
	Bank material		✓	✓	✓					✓	✓		
	Riparian vegetation structure	✓	PA	✓	PA		✓		✓	✓	✓	✓	
	Long. continuity riparian veg.	✓		✓			✓		✓		✓	✓	
	Riparian vegetation width		✓	✓	✓				✓		✓	✓	
	Riparian veg. composition		✓	pa	✓							✓	
	Artificial features/structures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Land use	✓	✓		✓	✓	✓		PA	✓	✓	✓	
D - FLOODPLAIN	Fluvial forms		✓	✓	✓		✓		✓	✓		✓	
	Floodplain dimensions		✓	✓	✓				✓	PA			
	Floodplain deposits		✓	✓	✓				PA				
	Land use	✓	✓	✓	✓	✓	✓	PA	PA	✓		✓	
3. RIVER PROCESSES													
A - LONGITUDINAL CONTINUITY		✓	✓		✓	✓	✓	PA	✓	✓	✓	✓	
B - LATERAL CONTINUITY		✓	✓	✓	✓	✓	✓	PA	✓	✓	✓	✓	
D - BANK EROSION / STABILITY			✓	✓	✓		✓	PA	✓	✓	✓	✓	
E - CHANNEL ADJUSTMENTS		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
F - VERTICAL CONTINUITY		PA					✓			✓		✓	

Table 13 Analyzed methods for morphological assessment for non-European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from non-European countries (Morphological assessment)			RSF	GI	GAI	NCD	WARSSS	CEM	RGA	SCS-RGA	SCRS	CMA	SAP
1. METHOD CHARACTERISTICS													
A - SOURCE OF INFORMATION / DATA COLLECTION		Map/Remote sensing	✓	✓		✓	✓		PA	PA	✓	✓	✓
		Field survey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Rapid field assessment							✓	✓			
		Modelling											PA
B - SPATIAL SCALE	LONG. SPATIAL SCALE	Fixed length											
		Length vs width											
		Variable length	✓	✓	✓	PA	PA	PA	PA	✓	PA	PA	✓
	LATERAL SPATIAL SCALE	Channel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Banks/Riparian zones	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Floodplain	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
C - TEMPORAL SCALE		Present	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Recent	✓	✓				PA	✓	✓		✓	PA
		Historical	✓	✓				PA	✓	✓		✓	PA
D - TYPE OF METHOD		Characterization/Classification							✓	✓	✓	✓	✓
		Assessment by index	PA	✓	✓	✓	✓		✓	✓		✓	PA
		General assessment/Design	✓	✓	✓	✓	✓	✓					
E - REFERENCE CONDITIONS			✓	✓	✓	✓	✓	PA	PA	PA		✓	✓
2. RECORDED FEATURES													
A - CATCHMENT / VALLEY		Large scale characteristics	✓	✓	✓	✓	✓	✓			✓	✓	✓
		Hydrological regime/Discharge	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
		Valley form/features	✓	✓	✓	✓	✓				✓		✓
B - CHANNEL		Channel pattern/planform	✓	✓	✓	✓	✓	✓	✓	✓	PA		✓
		Channel forms	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
		Channel dimensions	✓	✓	PA	✓	✓	PA	✓		✓		✓
		Flow-type	✓	✓	✓								
		Substrate	✓	✓	✓	✓	✓		✓	✓	✓		✓
		Physical parameters			PA	✓	✓				✓		✓
		In-channel vegetation	✓	✓									
		Woody debris	✓			✓	✓		✓	✓			
		Artificial features/structures		✓	✓	✓	✓	✓	PA	PA		✓	✓
C - RIVER BANKS/ RIPARIAN ZONE		Bank profile/shape	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
		Bank material	✓		✓						✓		PA
		Riparian vegetation structure	✓	✓		✓	✓	✓	✓		✓		
		Long. continuity riparian veg.		✓									
		Riparian vegetation width											
		Riparian veg. composition	✓				PA						
		Artificial features/structures		✓	✓	✓	✓	✓	✓	PA		✓	PA
		Land use		✓	PA							✓	✓
D - FLOODPLAIN		Fluvial forms	✓						✓		✓		
		Floodplain dimensions				✓	✓				✓	✓	✓
		Floodplain deposits			✓				✓	✓	✓		
		Land use		PA			✓			PA	PA	✓	✓
3. RIVER PROCESSES													
A - LONGITUDINAL CONTINUITY			✓	PA	✓		PA	✓				✓	
B - LATERAL CONTINUITY			✓	PA	✓	PA	✓	✓	PA	PA	✓	✓	
D - BANK EROSION / STABILITY			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
E - CHANNEL ADJUSTMENTS			✓	✓		✓	✓	✓	✓	✓		PA	✓
F - VERTICAL CONTINUITY					✓			PA	PA	PA			

2.3.1 Method characteristics

Compared to previous categories, morphological methods give a greater importance to data derived from maps and remote sensing (83% and 64% for European and non-European methods respectively)(Figure 12 and Figure 13). The types of assessment are almost equally subdivided in terms of features inventorying, quality assessment (index) and framework design, both for European and non-European methods. Some methods combine a general morphological assessment with a quality assessment (e.g. the English GAP, the Scottish MImAS), whereas others combine feature inventory and the assessment by a final index (e.g. the Czech HEM). Methods like the NCD (Rosgen, 1996), combine general framework design and the use of prediction indices aimed to evaluate some specific component or process (e.g. BEHI, Bank Erodibility Hazard Index). Some methods include a morphological risk assessment (e.g. the Scottish MimAS; the French SYRAH-CE). Other methods are a part of larger assessment protocols, for example the section n.1 of the HIDRI (Munné et al., 2006) which represents just a site morphological characterization, or the CMA from Oregon (OWEB, 2000) which, combined with other protocols, supports a final Watershed Condition Evaluation. This is also the case for the recent River Styles® Geomorphic Condition (RSGC), developed on the basis of the RSF by Brierley and Fryirs (2005), which has been incorporated in the River Condition Index assessment protocol (Healey et al., 2012) to specifically assess the physical component (forms) of the overall assessment of river condition.

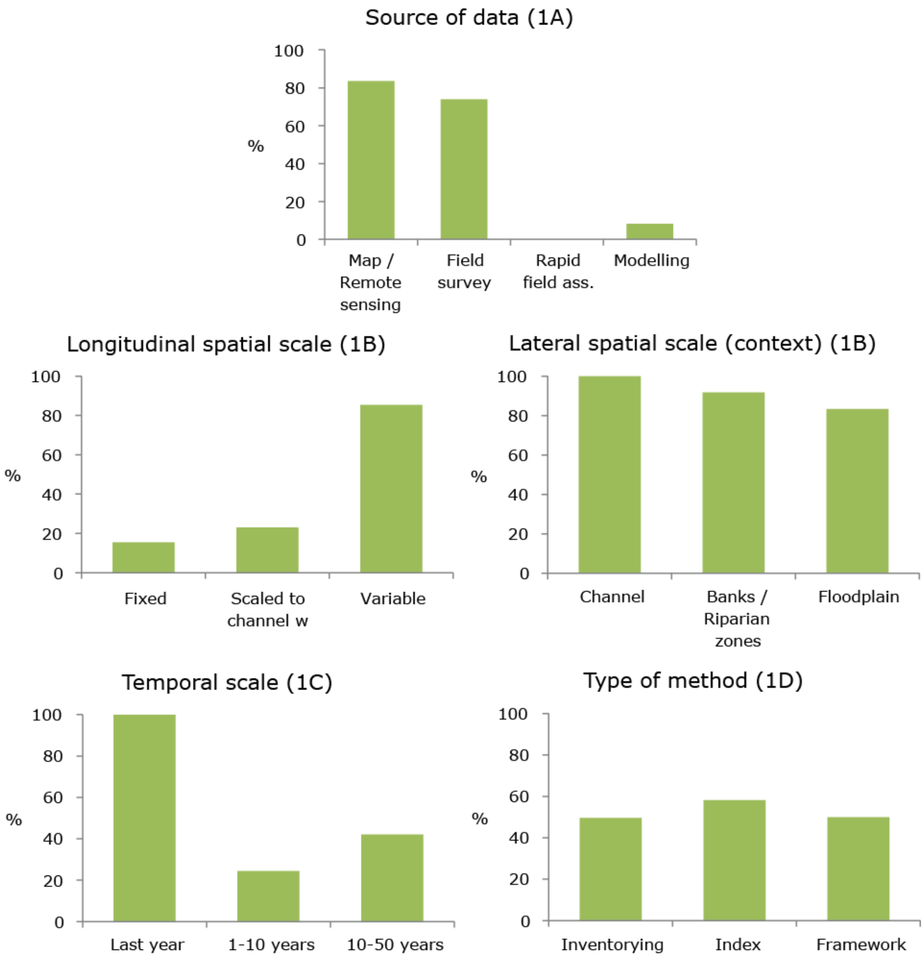

Figure 12 Synthesis of general information recorded by European methods for morphological assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

The main objective of these methods still remains the evaluation of present physical river conditions, but a greater proportion of methods, compared to the previous categories, also take into account recent and past changes (especially for non-European methods) by using maps and remote sensing.

The selection of assessment reaches is mainly based on the definition of homogenous reaches. Generally these methods focus on the overall river corridor (>80% for channel, banks and floodplain).

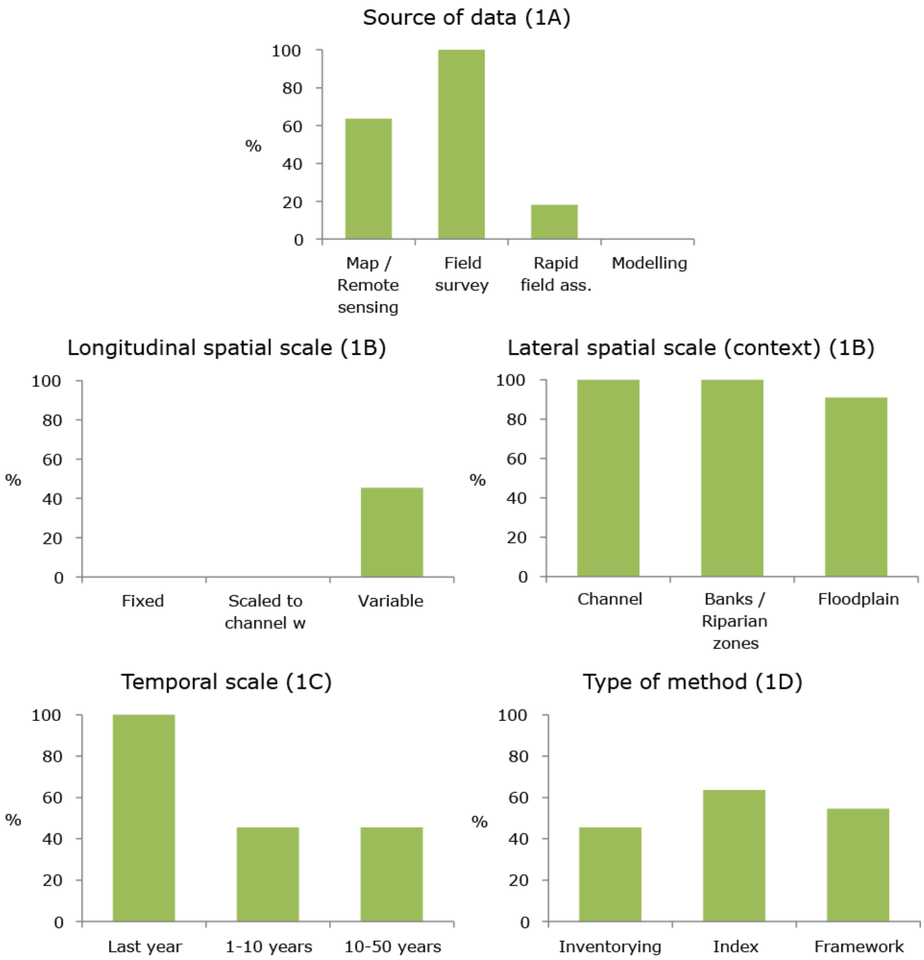

Figure 13 Synthesis of general information recorded by non-European methods for morphological assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

2.3.2 Recorded features

Most morphological methods record large scale characteristics (general and valley features), and a very large proportion of both European and non-European methods also consider hydrological conditions in terms of hydrological alterations, but these are mainly qualitatively assessed (Figure 14 and Figure 15). Concerning channel features, European methods consider mainly artificial features, channel pattern, bed forms and channel dimensions, as well as bed substrate. The situation is similar for non-European methods (Figure 14 and Figure 15). As in the case of physical habitat assessment methods, channel substrate characteristics concern mainly sediment size and composition. Few methods attempt an assessment of bed substrate alteration, such as channel armouring and clogging (or embeddedness) (e.g. the French Aurah-CE; the Italian MQI; the Scottish MImAS).

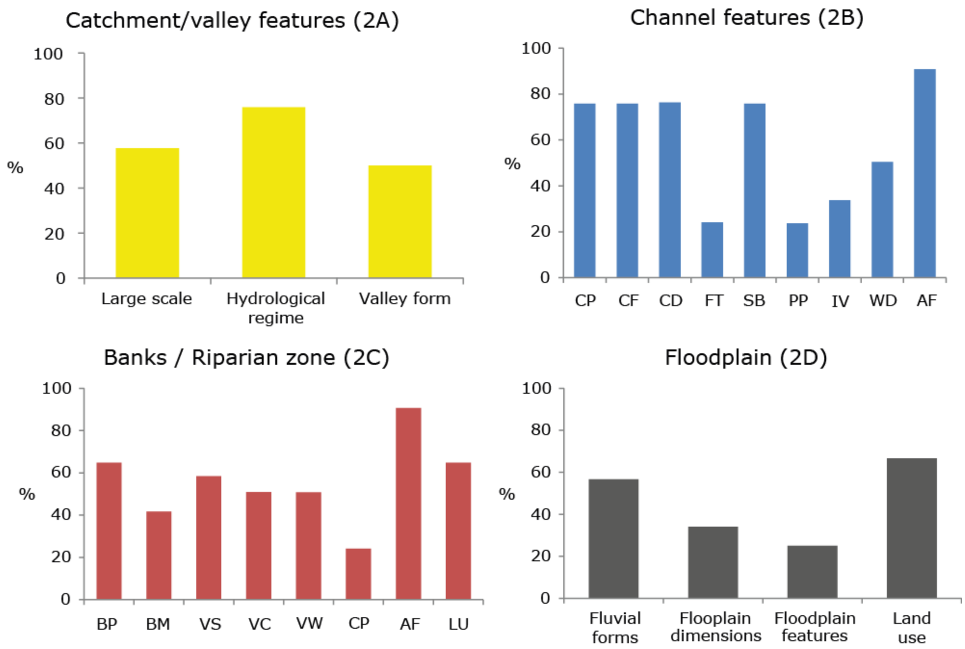

Figure 14 Features recorded by European methods for morphological assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; PP, physical parameters; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; CP, vegetation composition; AF, artificial features; LU, land use

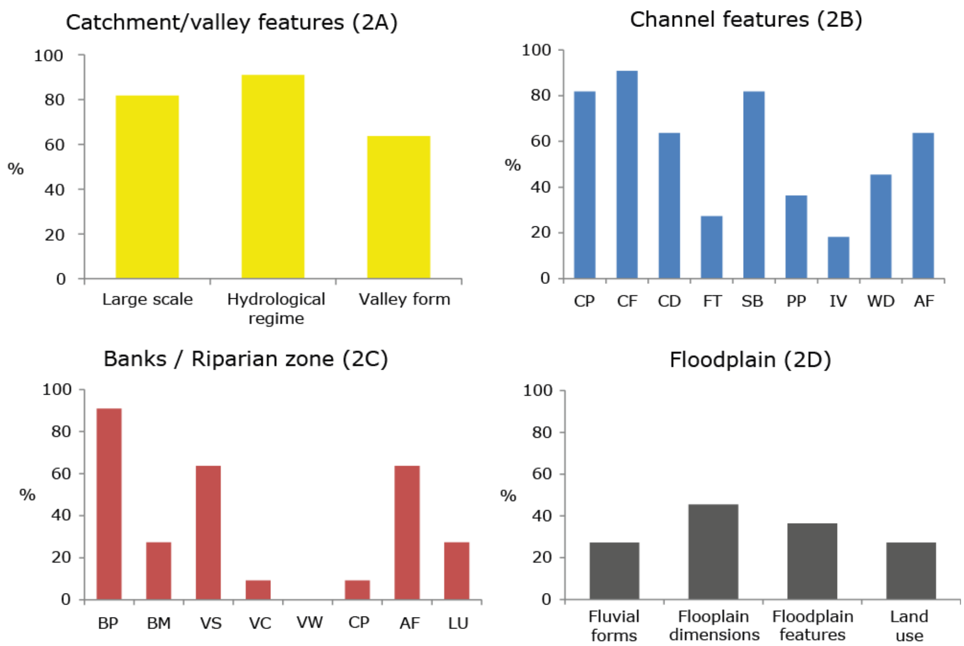

Figure 15 Features recorded by non-European methods for morphological assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Channel features: CP, channel pattern; CF, channel forms; CD, channel dimensions; FT, flow-types; SB, substrate; PP, physical

parameters; IV, in-channel vegetation; WD, woody debris; AF, artificial features. Banks/Riparian zones features: BP, bank profile; BM, bank material; VS, vegetation structure; VC, vegetation continuity; VW, vegetation width; CP, vegetation composition; AF, artificial features; LU, land use

The assessment of banks and riparian zones differs between European and non-European methods. The former pay more attention to physical and structural modifications (i.e. artificial features), whereas the latter focus on morphological characteristics associated with erosion processes (e.g. bank profile). The degree to which riparian vegetation characteristics are incorporated varies between methods (Figure 14 and Figure 15).

Compared to previous categories, morphological methods dedicate greater attention to floodplain features (e.g. floodplain dimension, type of soil).

2.3.3 River processes

In sympathy with the features that are recorded, European methods give great importance to river continuity (flow, sediment and matter, both laterally and longitudinally) and also to channel adjustments; whereas non-European methods focus most heavily on bank erosion and channel adjustments (e.g. RGAs, Moe, 1999; Simon & Downs, 1995; Simon, 2003). Large scale sediment continuity remains poorly considered (some exceptions: the English FA; the Italian MQI). A very small portion of methods directly considers vertical continuity (connection to groundwater) (Figure 16).

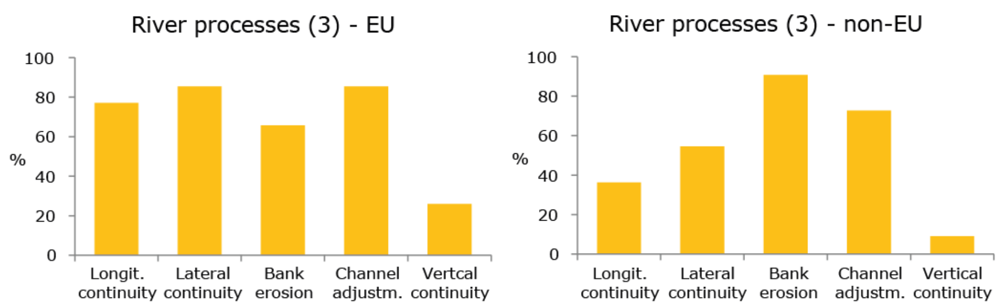

Figure 16 Information on river processes considered by European (on the left) and non-European (on the right) methods for the morphological assessment (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

2.4 Assessment of hydrological regime alteration

Methods for the assessment of hydrological regime alteration analyze specific hydrological indicators of rivers and streams to assess the impact of human pressures on the hydrological regime. They often focus on alterations which affect the longitudinal continuity of water flow (e.g. intakes, impoundment, diversions) and mainly focus on the reach scale. Methods widely use models to obtain data from ungauged reaches or incomplete data series. We reviewed 10 methods in total (4 for European countries and 6 for non-European countries).

This category includes methods specifically developed for the assessment of hydrological regime alteration (e.g. IAHRIS in Spain). Some hydrological evaluations or indicators are also included in the previous categories. For example, some morphological assessment methods include only those hydrological aspects having significant effects on geomorphic processes (e.g. channel-forming discharge).

Environmental flows ("Eflows") methods are not covered in this paragraph, although they usually start from a basic evaluation of the modifications in flow regime from near-natural conditions. This is because the specific aim of environmental flow methods is to assess flow requirements of the many interacting components of aquatic systems (Arthington, 1998; King et al., 2008) (see also section 2.8), and the output is a description of a flow regime needed to achieve and maintain a specified river condition. Differently, hydrological alteration methods reviewed in this section are specifically focussed on the assessment of the flow regime alterations, and the typical output is an index evaluating the degree of deviation from unaltered conditions.

At both European and international scale, compared to the other categories of assessment, relatively few methods exist for the identification and quantification of hydrological regime alteration, even though the scientific community agree on the basic components of the hydrological regime to be assessed (Bussettini et al., 2011). In fact, most methods analyze possible alterations of the five main components of the hydrological regime (i.e. magnitude, frequency, timing, duration, rate of change of discharges), making use of some or all the Indicators of Hydrologic Alteration (IHA; Richter et al. 1996; Poff et al., 2003).

Table 14 and Table 15 summarize the key and analyzed references for each assessment method. Definitions for table entries are given in Appendix B. Table 16 and Table 17 synthesize the information on methods for the assessment of hydrological regime alteration for European and non-European countries respectively.

Table 14 Analyzed references for methods of hydrological regime alteration assessment for European countries

Method from European countries (Hydrological regime alteration)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Indice di Alterazione del Regime Idrologico	IARI	Italy	Ispra (2011)	Original reference
Dundee Hydrological Regime Alteration Method	DHRAM	Scotland	Black et al. (2005)	Original reference
Indices de Alteración Hidrológica en Ríos - Indicators of Hydrologic Alteration in Rivers	IAHRIS	Spain	Martínez Santa-María & Fernandez Yuste (2010)	Original reference; Fernandez Yuste et al. (2008)
HIDRI - Protocolo 3: Cumplimiento de caudales de mantenimiento	QM - HIDRI	Spain	Munné et al. (2006)	Original reference

Table 15 Analyzed references for methods of hydrological regime alteration assessment for non-European countries

Method from non-European countries (Hydrological regime alteration)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Hydrology driver Assessment Index	HAI	South Africa	Kleynhans et al. (2005)	Original reference
Histogram Matching Approach	HMA	Taiwan	Shiau & Wu (2008)	Original reference
The Indicators of Hydrologic Alteration	IHA	US	The Nature Conservancy (2009)	Original reference; Richter et al. (1996)
Range of Variability Approach	RVA	US	Richter et al. (1998)	Original reference
Hydrological Condition Assessment	HCA	US	OWEB (2000)	Original reference
Hydrologic Index Tool	HIT	US	Henriksen et al. (2006)	Original reference

Table 16 Analyzed methods for hydrological regime alteration assessment for European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from European countries (Hydrological regime alteration)		IARI	DHRAM	IAHRIS	QM (HIDRI)
1. METHOD CHARACTERISTICS					
A - SOURCE OF INFORMATION / DATA COLLECTION	Map/Remote sensing	✓	✓		
	Existing hydrological data series	✓	✓	✓	✓
	Monitoring or measurement (field)				✓
	Modelling	✓	✓	✓	✓
B - SPATIAL SCALE	River catchment		PA		
	Water body	✓			✓
	Reach	✓	✓	✓	✓
	Cross section	✓		✓	✓
C - TEMPORAL SCALE	Monthly data	✓	✓	✓	
	Daily data	✓	✓	✓	
	Hourly data				
	Other	PA	PA		✓
D - RIVER TYPOLOGY APPLICATION	Not limited to specific river typologies	PA	✓	PA	✓
	Limited to specific river typologies				
E - TYPE OF ASSESSMENT	Single index	✓	✓		
	Multiple index			✓	✓
	Modelling			✓	
	Final expert judgment	✓			
F - REFERENCE CONDITION	Known pre-impact natural condition	✓	✓	PA	
	Reconstructed pre-impact natural condition	✓	✓		PA
G - PREDICTIVE ABILITY	Models and scenarios for evaluation of pressure changes			✓	
	Models and scenarios for evaluation of restoration measures			✓	
	No predictive assessment	✓	✓		
H - STRENGTHS / GAPS OF THE METHOD	Easy to apply				✓
	Applicability for different lengths of data series	✓			
	Procedure for gauged/ungauged stations	✓	✓	PA	✓
	A priori evaluation of pressures	✓	✓		
I - CONNECTION TO ECOLOGY	Influence on ecological status		PA	✓	PA
2. RECORDED FEATURES					
A - HYDROLOGICAL CONDITIONS	Flow regime	✓	✓	✓	
	Discharge	✓	✓	✓	✓
	Changes in flow depth				✓
	Flow velocity				✓
	Shear stress				
	Other				✓
B - METRICS OF FLOW REGIME	Magnitude	✓	✓	✓	
	Frequency	✓	✓	✓	
	Duration	✓	✓	✓	
	Timing (seasonality)	✓	✓	✓	
	Rate of change (rapidity)	✓	✓	PA	
	Minimum flow	✓	✓	✓	
	Maximum flow	✓	✓	✓	
	Variability (annual)	✓		✓	
	Interannual variability (climate)	✓		✓	
	Intermittent flows				
C - ASSESSED PRESSURES	Intakes, transfers and by-passes of water	✓	✓	PA	PA
	Groundwater interaction	✓	✓	✓	
	Hydro-peaking	PA	PA		
	Impoundment - change in hydrology	✓	✓	✓	PA
	Lateral/vertical adjustments - change in hydrology			PA	
	Large scale pressures (e.g. land use)	✓	PA		PA

Table 17 Analyzed methods for hydrological regime alteration assessment for non-European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from non-European countries (Hydrological regime alteration)		HAI	HMA	IHA	RVA	HCA	HIT
1. METHOD CHARACTERISTICS							
A - SOURCE OF INFORMATION / DATA COLLECTION	Map/Remote sensing	✓			✓	✓	
	Existing hydrological data series	✓	✓	✓	✓	✓	✓
	Monitoring or measurement (field)						
	Modelling	✓	✓	✓		✓	✓
B - SPATIAL SCALE	River catchment	PA		PA	PA	✓	
	Water body	PA		PA	✓	✓	
	Reach	✓	✓	✓	✓		✓
	Cross section		✓	PA			
C - TEMPORAL SCALE	Monthly data	✓	✓			✓	
	Daily data	✓	✓	✓	✓		✓
	Hourly data						
	Other	PA					✓
D - RIVER TYPOLOGY APPLICATION	Not limited to specific river typologies	✓	PA	✓	✓	PA	✓
	Limited to specific river typologies						
E - TYPE OF ASSESSMENT	Single index	✓			✓		
	Multiple index	PA	PA	PA		✓	✓
	Modelling		✓		PA		PA
	Final expert judgment	✓			PA		
F - REFERENCE CONDITION	Known pre-impact natural condition	✓	✓	✓	✓	✓	
	Reconstructed pre-impact natural condition						PA
G - PREDICTIVE ABILITY	Models and scenarios for evaluation of pressure changes	PA	✓	PA	PA	PA	PA
	Models and scenarios for evaluation of restoration measures		✓	PA	PA		
	No predictive assessment						
H - STRENGTHS / GAPS OF THE METHOD	Easy to apply					✓	
	Applicability for different lengths of data series						PA
	Procedure for gauged/ungauged stations		✓				
	A priori evaluation of pressures		✓	✓	PA	✓	
I - CONNECTION TO ECOLOGY	Influence on ecological status	✓	✓	PA	✓		✓
2. RECORDED FEATURES							
A - HYDROLOGICAL CONDITIONS	Flow regime	✓	✓	✓	✓	✓	✓
	Discharge	✓	✓	✓	✓		✓
	Changes in flow depth			PA			
	Flow velocity						
	Shear stress						
	Other					✓	
B - METRICS OF FLOW REGIME	Magnitude		✓	✓	✓		✓
	Frequency		✓	✓	✓		✓
	Duration	✓	✓	✓	✓		✓
	Timing (seasonality)	✓	✓	✓	✓	✓	✓
	Rate of change (rapidity)		✓	✓	✓		✓
	Minimum flow	✓	✓	✓	✓	✓	✓
	Maximum flow	✓	✓	✓	✓	✓	✓
	Variability (annual)						✓
	Interannual variability (climate)		✓				✓
	Intermittent flows						PA
C - ASSESSED PRESSURES	Intakes, transfers and by-passes of water	✓	✓	✓	✓	✓	
	Groundwater interaction	✓	PA	✓	✓	✓	
	Hydro-peaking	PA				PA	
	Impoundment - change in hydrology	✓	✓	✓	✓	✓	
	Lateral/vertical adjustments – change in hydrology	PA					
	Large scale pressures (e.g. land use)	PA		✓		✓	

2.4.1 Method characteristics

This category of methods uses existing hydrological data or data from modelling techniques (Figure 17 and Figure 18). Models are applied mainly where data are not available or to fill gaps in incomplete data series (e.g. IARI in Italy). Maps and remote sensing analysis are commonly used to get an overview of human pressures at the catchment scale (a priori evaluation of pressure), or simply to characterize the river and/or catchment and the sites of application. Amongst reviewed methods, only the Spanish QM-HIDRI (Munné et al., 2006) incorporates specially collected field measurements of flow conditions. The IARI includes field measurements in ungauged reaches to characterize and assess the present hydrological condition.

Most of the methods synthesize the assessment into a final (or multiple) index. The assessment focuses essentially on the reach scale, and incorporates averaged monthly and daily data.

Both European and non-European methods have a high predictive ability (Table 16 and Table 17), even though a low proportion of methods build scenarios to model restoration success or to assess the impact of specific changes (Figure 17 and Figure 18). In general, these methods have no limitations in terms of river typology (Table 16 and Table 17).

All of the methods have a more or less direct link to the ecological components of the hydrosystem (Table 16 and Table 17). For example, the aim of the South African HAI is to determine the degree to which the hydrological regime has changed from the reference hydrological conditions, and to assess the ecological response to this change to obtain the present hydrological ecological status (Ecostatus).

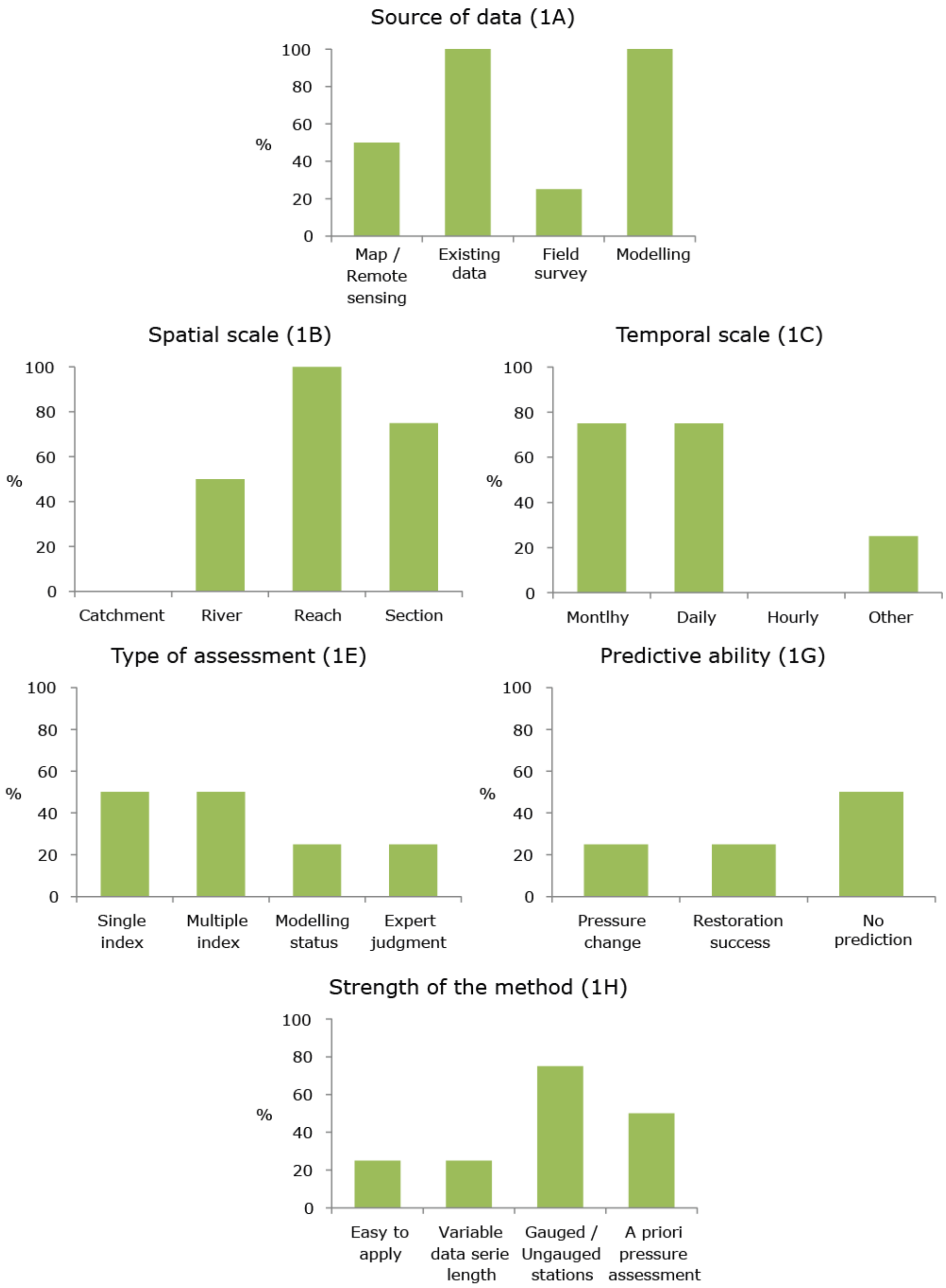

Figure 17 Synthesis of general information recorded by European methods for the assessment of hydrological regime alteration (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

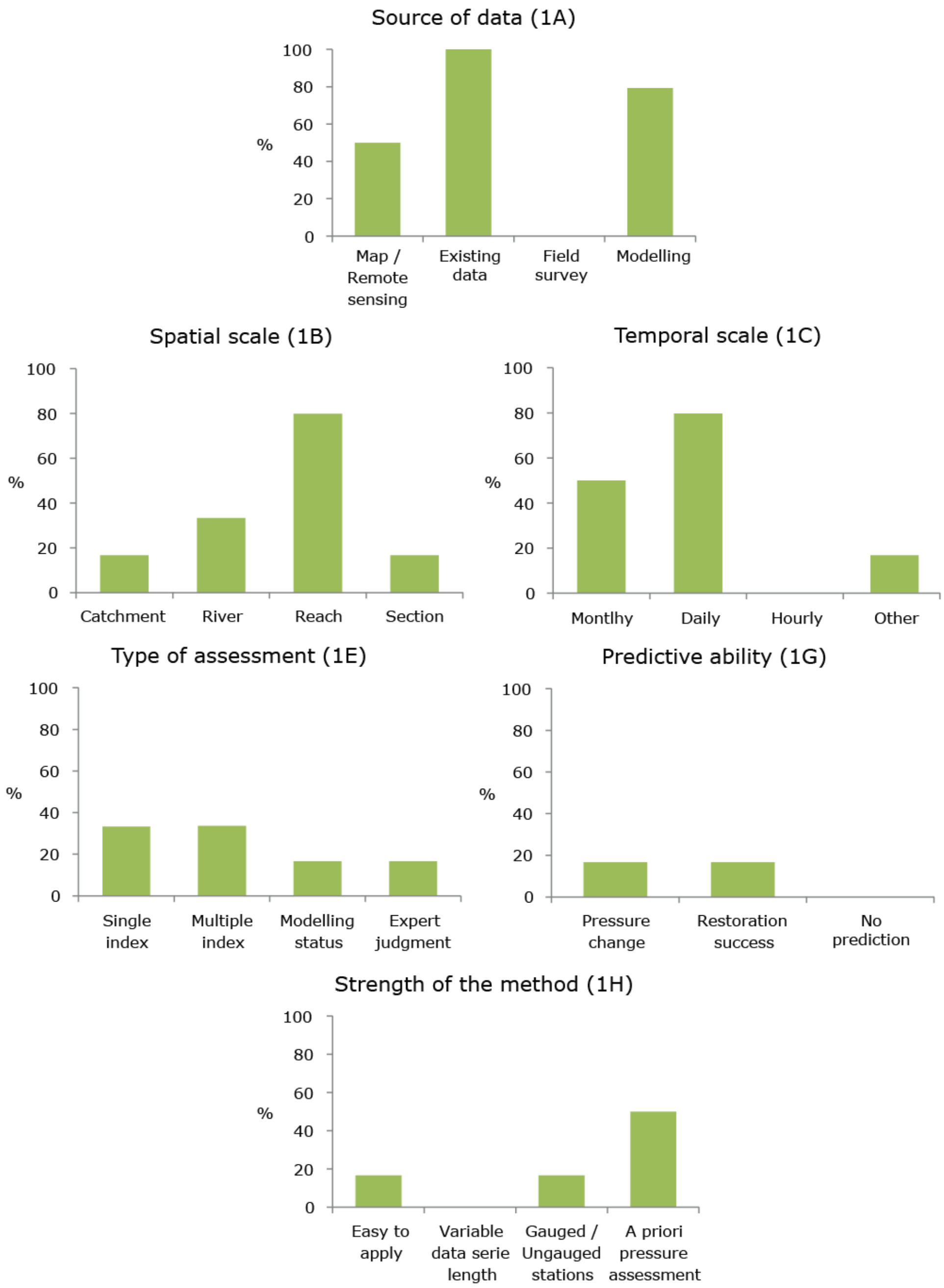

Figure 18 Synthesis of general information recorded by non-European methods for the assessment of hydrological regime alteration (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none

Methods differ in terms of their key strengths. Whereas European methods use indicators and parameters applicable to both gauged and ungauged sites (Figure 17), non-European methods place a greater importance on the a priori identification of impacts and causes of hydrological alteration (Figure 18). These influence the approach used to define reference conditions: European methods combine known and modelled reference conditions, depending on available data, whereas non-European methods are based on the knowledge of pre-impact reference conditions (Table 16 and Table 17).

2.4.2 Recorded features

Concerning the recorded features, all methods are focussed on the assessment of flow regime and discharge (Figure 19 and Figure 20), employing data available from models and/or existing data series. The QM-IDRI (Munné et al., 2006), a field-based method, also records cross-section data such as river flow velocity and depth. The HCA, a large scale assessment method (OWEB, 2000), combines watershed land use characteristics (e.g. coverage, density) with hydrological data.

For all methods, metrics of flow regime are based on the 5 main components of the flow regime (discharge magnitude, frequency, duration, timing, rate of change) (Richter et al. 1996; Poff et al., 2003). Some methods also evaluate temporal variability (annual = seasons; inter-annual = climatic changes) (Figure 19 and Figure 20).

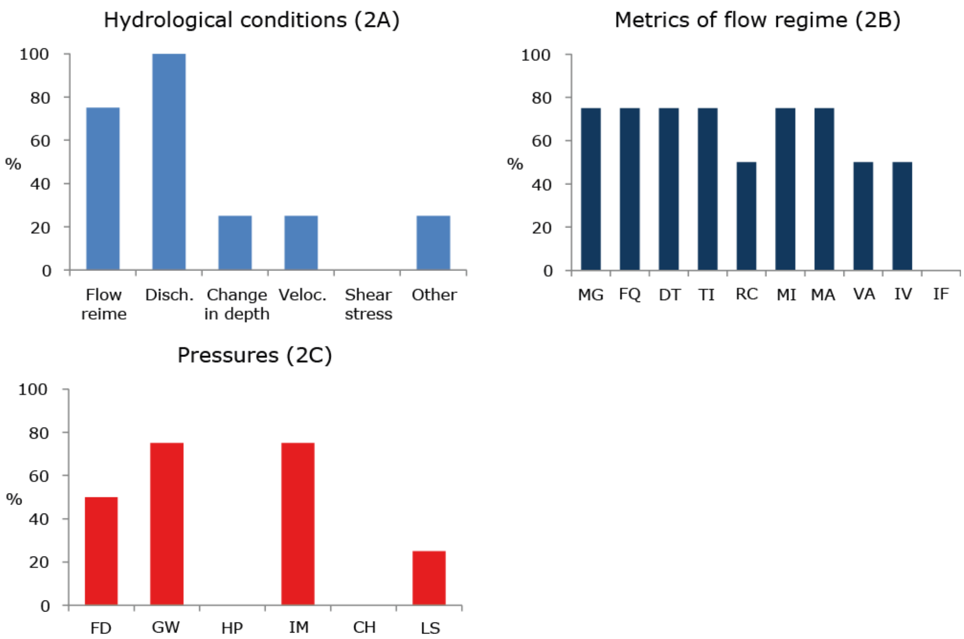

Figure 19 Features collected by European methods for the assessment of hydrological regime alteration (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Metrics of flow regime: MG, magnitude, FQ, frequency; DT, duration; TI, timing ; RC, rate of change; MI, minimum flow; MA, maximum flow; VA, variability (annual); IV, inter-annual variability; IF, intermittent flow. Pressures: FD, flood diversions; GW, groundwater interactions; HP, hydro-peaking; IM, impoundment; CH, channel changes; LS, large scale pressures

Few differences exist between European and non-European methods in terms of assessed pressures (Figure 19 and Figure 20): the effects of dams and weirs on longitudinal continuity (impoundment), as well as the impacts of water intakes and diversions on the natural regime, and the consequences of water abstraction

on groundwater. No methods evaluate directly the effect of hydro-peaking from power generation plants: methods based on IHA are limited by the data format (averaged daily data). DHRAM and IARI can potentially be used for this purpose with the condition that sub-daily data are collected. Indirectly, the HCA Watershed assessment takes into account hydro-peaking as a consequence of morphological alteration (category of methods 3, Section 2.3).
Hydrological assessment methods do not consider physical and spatial relationships between the river and its floodplain (lateral continuity = consequence of dykes, levees or as consequence of incision) and only a few methods assess the consequences of river degradation (e.g. the African HAI in terms of vertical connectivity; Figure 19 and Figure 20).

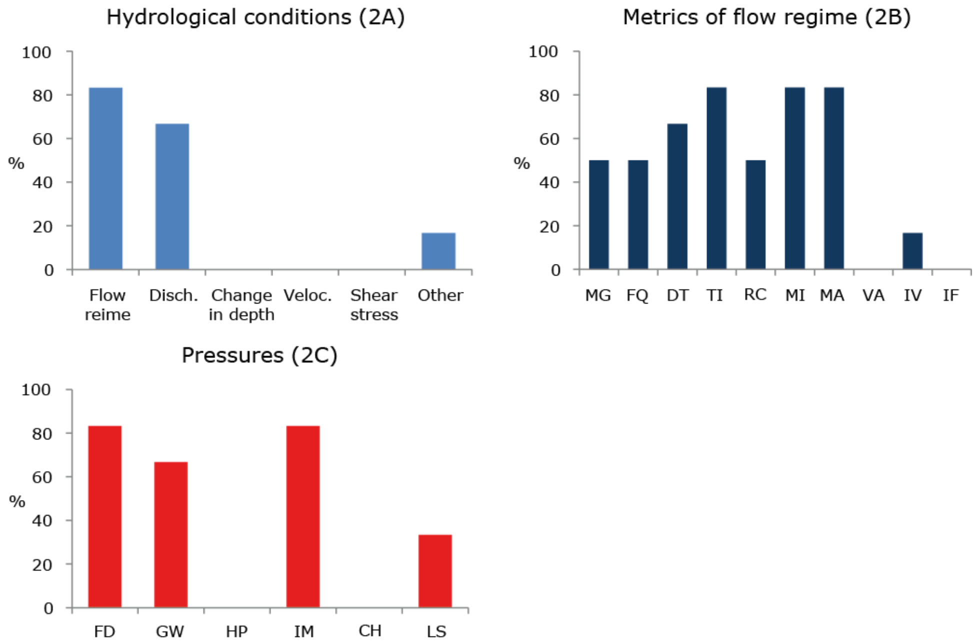

Figure 20 Features collected by non-European methods for the assessment of hydrological regime alteration (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Metrics of flow regime: MG, magnitude, FQ, frequency; DT, duration; TI, timing ; RC, rate of change; MI, minimum flow; MA, maximum flow; VA, variability (annual); IV, inter-annual variability; IF, intermittent flow. Pressures: FD, flood diversions; GW, groundwater interactions; HP, hydro-peaking; IM, impoundment; CH, channel changes; LS, large scale pressures

2.5 Fish longitudinal continuity assessment

Methods for fish longitudinal continuity assessment aim to assess the impact that cross-sectional structures (i.e. barriers) have on the movement and migration of fish communities. While early methods simply aim to obtain a database inventory of the location of barriers, more recent methods also attempt to assess the passability of barriers (mainly at the single barrier scale) both in terms of their structural characteristics and of the biological capacities of fish communities to pass them (e.g. swimming/jumping abilities, life history). We reviewed 20 methods in total (13 for European countries and 7 for non-European countries).

This category includes methods developed to assess river longitudinal continuity for fish communities. Some assessment of fish continuity can also be included in the previous categories.

This type of assessment is relative recent. Traditional methods use biological sampling (i.e. radio-tracking, capture of marked individuals, etc.) (Kemp & O'Hanley, 2010) or aim to get a database inventory of the location of barriers in the river/catchment (e.g. WeBDD in Belgium, RDB & DRN in England). Recent methods combine field barrier characterisation and biology information to get a more detailed assessment of barrier passability (e.g. ICE in France; Spanish indices developed in the Duero basin).

The present review of this method category is based on the recent exhaustive review made by Kemp & O'Hanley (2010), which took into account methods for assessment of longitudinal continuity for fish communities in Europe and North America, and aimed to give indications to prioritize restoration actions (e.g. barrier removal, creation of fish pass, etc.).

Table 18 and Table 19 summarize the key and analyzed references for each assessment method. Definitions for table entries are given in Appendix C. Table 20 and Table 21 synthesize the information on methods for fish longitudinal continuity assessment for European and non-European countries respectively.

Table 18 Analyzed references for assessment methods for longitudinal continuity for fish communities for European countries

Method from European countries (Longitudinal continuity)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Qualitative Scoring System	QSS	Austria	Zitek et al. (2008)	Original reference; Kemp & O'Hanley (2010)
Radio-Telemetry	R-T	Belgium	Ovidio et al. (2007)	Kemp & O'Hanley (2010)
Web-based Database	WebDB	Belgium (Flanders)	Monden et al. (2000)	Kemp & O'Hanley (2010)
National Fish Passage Improvement Prioritisation Methodology	NFPIPM	England & Wales	Environmental Agency	Kemp & O'Hanley (2010)
River Barrier dataset + Detailed River Network	RDB + DRN	England & Wales	EA (2010)	Kemp & O'Hanley (2010)
Information sur la Continuité Ecologique	ICE	France	Baudoin (ONEMA) (2011)	Original reference
Référentiel national des Obstacles à l'Ecoulement	ROE	France	ONEMA (2010); Baudoin (ONEMA) (2011)	Original references
Barrier assessment standard methodology & Querbauwerke-Information System	BA & QuIS	Germany	Dumont (2005)	Kemp & O'Hanley (2010)
Indici di Priorità d'intervento (Priority Indices)	IPs & IPt	Italy	Pini Prato (2007)	Original reference
Empirical assessment of passability of weirs	EAPW	Netherlands	Winter & Van Densen (2001)	Kemp & O'Hanley (2010)
Morphology Pressure Database	MPD	Scotland	Kemp et al. (2008)	Kemp & O'Hanley (2010)
Índice de Conectividad Fluvial/ Index de Connectivitat Fluvial - Index of Fluvial Connectivity	ICF (HIDRI)	Spain	Munné et al. (2006); Sola et al. (2011)	Original reference
Índice de franqueabilidad, Índice de compartimentación, Índice de continuidad longitudinal, Índice de prioridad de actuación	IF, IC, ICL, IPA	Spain	Seisdedos Fidalgo et al. (2010)	Original reference

Table 19 Analyzed references for assessment methods for longitudinal continuity for fish communities for non-European countries

Method from non-European countries (Longitudinal continuity)				
Method	**Code**	**Country**	**Original reference**	**References analyzed**
Dendritic Connectivity Index	DCI	Canada	Cote et al. (2009); Bourne et al. (2011)	Original references
FishXing software	FishXing	Canada	Bourne et al. (2011)	Original reference
Fish migration barrier assessment protocol	FMBAP	US	Washington Department of Fish and Wildlife	Kemp & O'Hanley (2010)
The Oregon Fish Passage Data Standard	OFPDS	US	Oregon Department of Fish and Wildlife (ODFW)	Kemp & O'Hanley (2010)
Calfish project - The California Passage Assessment Database project	PAD	US	California Department of Fish and Game	Kemp & O'Hanley (2010)
Coarse Filter Assessment Methodology	CFAM	US	Coffman (2005) - US Forest Service	Kemp & O'Hanley (2010)
Fish and Fish Habitat Assessment	FFHA	US	OWEB (2000)	Original reference

Table 20 Analyzed methods for the assessment of longitudinal continuity for fish communities for European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from European countries (Longitudinal continuity)

		QSS	R-T	WebDB	NFPIPM	RBD + DRN	ROE	ICE	BA & QuIS	IPs & IPt	EAPW	MPD	ICF (HIDRI)	IF	IC	ICL	IPA
1.METHOD CHARACTERISTICS																	
A - DATA COLLECTION	Map/Remote sensing		✓	PA		✓	✓	✓	PA	✓		✓	✓		PA	PA	PA
	Field survey	✓	✓					✓		✓	✓	✓	✓	✓		PA	
	Rapid field assessment									✓							
	Existing database	✓		PA	✓	✓	✓	✓	✓	✓	✓	PA	✓	PA	PA	PA	PA
	Modelling										PA						
B - SPATIAL SCALE	River network	✓		✓	✓	✓	✓	PA	✓	✓		✓			PA	PA	PA
	River	✓		✓			✓	PA	✓	✓	✓	✓			✓	✓	✓
	Single barrier	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
C - HABITAT ASSESSMENT	Defined length								✓	PA		✓					✓
	Metrics to define habitats				PA					PA							
D - TYPE OF METHOD	Barrier passability assess.	PA	✓	PA	✓	PA	PA	✓	✓	PA	✓	✓	✓	✓	PA	✓	PA
	Barrier charact./Modelling		✓				PA	✓		PA				PA			
	DB inventorying/Mapping	PA		✓		✓	✓	PA	✓	✓		✓					PA
	Final index							✓		✓			✓	✓	✓	✓	✓
	Habitat loss assessment								✓	PA							PA
	Fish telemetry		✓														
E – CRITERIA FOR PASSABILITY ASSESSMENT	Fish biology	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓			
	Chemical attributes/Temp.		✓					✓			PA			PA			
	Temporal environ. variation							PA	PA		✓		PA	PA			
	Hydrological attributes		✓					✓			✓	✓	PA	✓			
	Physical attributes barrier					✓	✓	✓		✓		✓	✓	✓			
	Effect of multiple barriers	PA					PA		PA	✓	PA				PA	✓	
	Presence of a fish pass	✓						✓	✓				✓	✓			
	Downstream/Upstream p.	PA			✓				✓			✓	✓	✓			
F – FISH SPECIES APPLICATION	Life history/behaviour				✓	✓		✓		✓		✓	✓	✓	✓	✓	✓
	Species of interest	✓								PA	✓						
2.RECORDED FEATURES																	
A - LARGE SCALE PASSABILITY ASSESSEMENT	River network configuration																
	Number of barriers	✓				✓	PA		PA	✓					✓	✓	PA
	Spatial location of barrier	✓		✓		✓	✓	PA	✓	✓					PA	PA	PA
	Natural/artificial barrier							PA	PA			✓					
	Segment/river length	✓							✓	PA					✓	✓	✓
	River flow parameters	✓						PA			✓						✓
B - BARRIER CHARACTERISTICS (BARRIER SCALE)	Flow parameters		✓					✓			✓	✓	✓	✓			
	Cross-section topography		✓					✓									
	Physical attributes		✓				✓	✓		✓		✓	✓	✓			
	Inflow/Outflow height		✓			✓	✓	PA					✓	✓			
	Presence outflow pool												PA	✓			
	Type of barrier			✓			✓	✓				✓	✓	✓			PA
	Presence bypass channel			PA				✓	✓				✓	✓			
C - FISH PASS CHARACTERISTICS	Natural/close to natural	✓		PA				✓					✓	✓			
	Technical fish pass	✓		PA				✓					✓	✓			
	General conditions fish pass	✓						✓					✓	✓			
	Passability of the fish pass	✓						✓	✓				✓	PA			
D - FISH CHARACTERISTICS	Age													PA			
	Life history	PA	PA					PA	✓	✓		✓	PA	✓		✓	✓
	Size range							✓			✓			PA			
	Swim/jump abilities							✓			✓			✓		✓	✓
	Fish species	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓
E – HYDROLOGICAL VARIABILITY	Times series of hydrological parameters							PA			✓		PA				✓

Table 21 Analyzed methods for the assessment of longitudinal continuity for fish communities for non-European countries ("✓"= present; " "= absent; "PA"= probably assessed)

Method from non-European countries (Longitudinal continuity)		DCI	FishXing	FMBAP	OFPDS	PAD	CFAM	FFHA
1.METHOD CHARACTERISTICS								
A - DATA COLLECTION	Map/Remote sensing						✓	✓
	Field survey		✓	✓	PA	PA	✓	✓
	Rapid field assessment		PA	PA				
	Existing database		✓		✓	✓	✓	✓
	Modelling	✓	✓	✓		✓	✓	
B - SPATIAL SCALE	River network	✓	PA	✓	PA	PA	PA	✓
	River	✓	PA	✓	PA	PA	PA	✓
	Single barrier		✓	✓	✓	✓	✓	✓
C - HABITAT ASSESSMENT	Defined length						✓	✓
	Metrics to define habitats			✓			✓	✓
D - TYPE OF METHOD	Barrier passability assessment	✓	✓	✓	PA	✓	✓	
	Barrier characterization/Modelling		✓		✓	✓		PA
	DB inventorying/Mapping			✓	✓	✓	✓	✓
	Final index							
	Habitat loss assessment			✓			✓	PA
	Fish telemetry							
E – CRITERIA FOR PASSABILITY ASSESSMENT	Fish biology	✓	✓	✓	PA	✓	✓	✓
	Chemical attributes/Temperature	✓						
	Temporal environmental variation		PA			✓		
	Hydrological attributes	✓	✓	✓		✓		✓
	Physical attributes of barrier	✓	✓	✓			✓	✓
	Effect of multiple barriers	✓					PA	
	Presence of a fish pass					✓		
	Downstream/Upstream passability	✓			PA	✓		PA
F – FISH SPECIES APPLICATION	Life history/behaviour	✓					✓	✓
	Species of interest		✓	✓		✓		✓
2.RECORDED FEATURES								
A - LARGE SCALE PASSABILITY ASSESSEMENT	River network configuration	✓						
	Number of barriers	✓						
	Spatial location of barrier	✓		✓	✓	✓	✓	PA
	Natural/artificial barrier	✓	✓		✓			✓
	Segment/river length	✓					✓	✓
	River flow parameters							
B - BARRIER CHARACTERISTICS (BARRIER SCALE)	Flow parameters		PA	✓		✓		✓
	Cross-section topography		PA					✓
	Physical attributes		✓	✓	✓	PA	✓	✓
	Inflow/Outflow height		✓				✓	✓
	Presence outflow pool		✓					✓
	Type of barrier			✓		✓	✓	✓
	Presence bypass channel					✓		PA
C - FISH PASS CHARACTERISTICS	Natural/close to natural							PA
	Technical fish pass					✓		
	General conditions fish pass							
	Passability of the fish pass							
D - FISH CHARACTERISTICS	Age							
	Life history	✓			PA	✓		✓
	Size range		✓					
	Swim/jump abilities		✓		PA	✓	✓	
	Fish species	✓		✓		✓	✓	✓
E – HYDROLOGICAL VARIABILITY	Times series of hydrological parameters							

2.5.1 Method characteristics

This category of methods employs data from several sources, reflecting the variety of existing methods (Figure 21 and Figure 22). In most cases these are not really assessment methods, but rather simple databases (e.g. the German QuIS; the French ROE). If the main objective is to get a large scale map inventory and localisation of barriers (often in the US), methods tend to use data from maps and remote sensing analysis (e.g. the FFHA in Oregon, the ROE in France). If the method aims to characterize barrier passability (the influence on ecological communities), the protocol collects field measurements of structure characteristics (e.g. the IF in Spain; the ICE in France), or biological sampling (e.g. the R-T in Belgium). Some methods also account for biological characteristics of fish communities and, in such case, make use of data derived from previous biological studies (databases) (e.g. the English NFPIPM). The most common aim of this category of methods is to support barrier management (prioritize actions, e.g. remove barrier and/or build fish pass). In some cases, the methods are used to help in identifying improved, more environmentally sustainable, methods for installing hydropower plants (Kemp and O'Hanley, 2010). A few methods combine the assessment of barrier passability and or/characterization and estimation of habitat loss (e.g. the German method), giving a broader ecological value (i.e. inclusion of other group of organisms). Compared to the previous category, only some European methods use a final index, where the main aim can be to give operational indications (e.g. priority indices, the IPs and IPt in Italy; the IPA the Spain), to assess the efficiency of fish passage (e.g. the Austrian QSS), or to provide information on the state of longitudinal continuity (e.g. the Spanish ICF), rather than a quality assessment. Indeed, none of these methods compares the state to any kind of reference condition. Most methods need to define the potential fish fauna for a given river reach (e.g. ICF in Spain).

The spatial scale of analysis often corresponds to the single barrier scale (80% of both European and non-European methods). The analysis at the river and network scales often consists of a simple database and map inventory of the number and location of barriers (Figure 23 and Figure 24).

When the method assesses the passability value (56% of European methods but probably or potentially more, and most non-European methods), the criteria to estimate this passability can vary according to: fish biological characteristics, physical and hydrological attributes of the barrier, passability in both upstream and downstream directions, presence of a fish pass (for European methods). The following additional criteria are incorporated in less than 30% of methods: chemical attributes (i.e. water temperature), temporal variation (i.e. hydrological conditions), and presence of multiple barriers. These methods rarely consider the effect of multiple barriers in a scale-integrated way (e.g. the Canadian DCI, the Spanish ICL), even though the collected features may potentially allow such an assessment (e.g. database/map inventory on barrier location, number and characteristics) (Figure 23 and Figure 24).

Generally European methods focus on large groups of target species, whereas in the US West Coast the assessment allows for specific fish communities (i.e. economic interest for fishing) (Table 20 and Table 21).

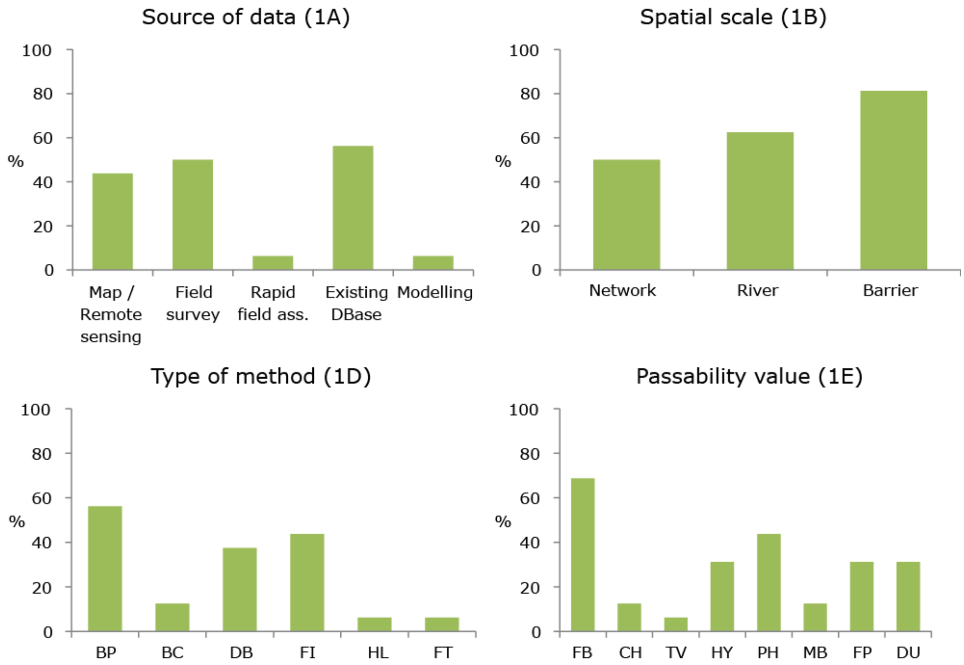

Figure 21 Synthesis of general information recorded by European methods for the assessment of longitudinal continuity for fish communities (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Type of method: BP, barrier passability assessment; BC barrier characterization/modelling; DB, database/map inventory; FI, final index; HL, habitat loss; FT, fish telemetry/radio-tracking. Passability value: FB, fish biology; CH, chemical attributes; TV, temporal variations; HY, hydrological attributes; PH, physical attributes; MB, effect of multiple barriers; FP, presence of a fish pass; DU, downstream/upstream passability assessment

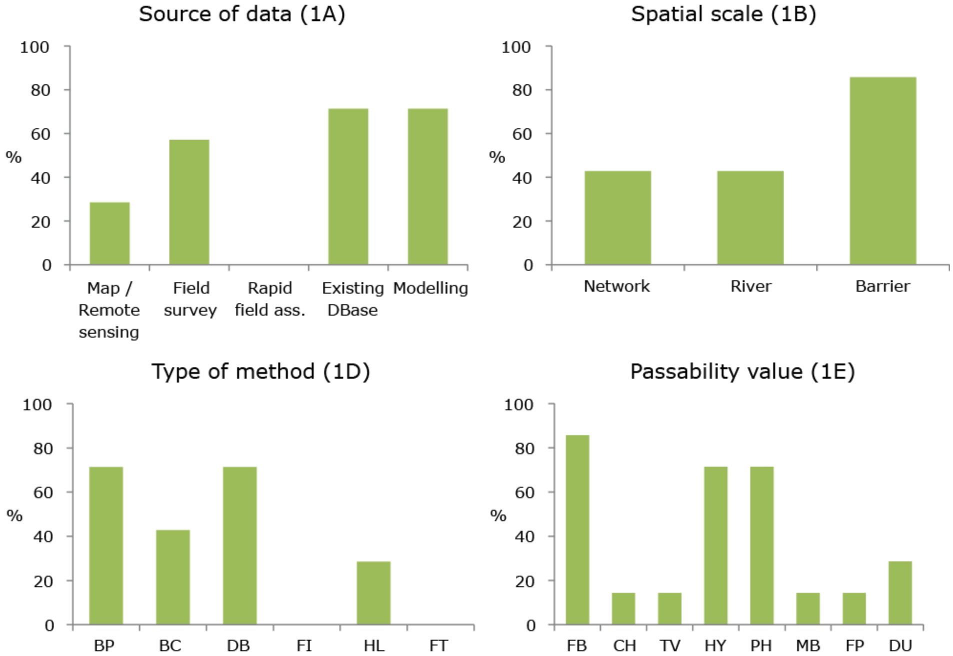

Figure 22 Synthesis of general information recorded by non-European methods for the assessment of longitudinal continuity for fish communities (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Type of method: BP, barrier passability assessment; BC barrier characterization/modelling; DB, database/map inventory; FI, final index; HL, habitat loss; FT, fish telemetry/radio-tracking. Passability value: FB, fish biology; CH, chemical attributes; TV, temporal variations; HY, hydrological attributes; PH, physical attributes; MB, effect of multiple barriers; FP, presence of a fish pass; DU, downstream/upstream passability assessment

2.5.2 Recorded features

Barrier characterization, both for the passability assessment and database inventory, differs between methods. In particular, European methods are not homogenous, whereas outside Europe it is common to collect information on the general physical attributes of barriers (e.g. height, slope, material). European methods place a greater importance on the presence (and characteristics) of a fish pass compared to non-European ones (Figure 23 and Figure 24; Table 20 and Table 21).

The most common features of fish communities considered by these methods are indications of species or groups of species present. A quite high proportion of methods (about the 38% and 43% for European and non-European methods respectively) attribute a value also to the fish life history behaviour (i.e. migratory species). Some methods (about the 31% and 43% for European and non-European methods respectively) collect information also on fish physiological characteristics, which correspond mainly to swimming and jumping abilities, which are then included in the evaluation of barrier passability (Figure 23 and Figure 24).

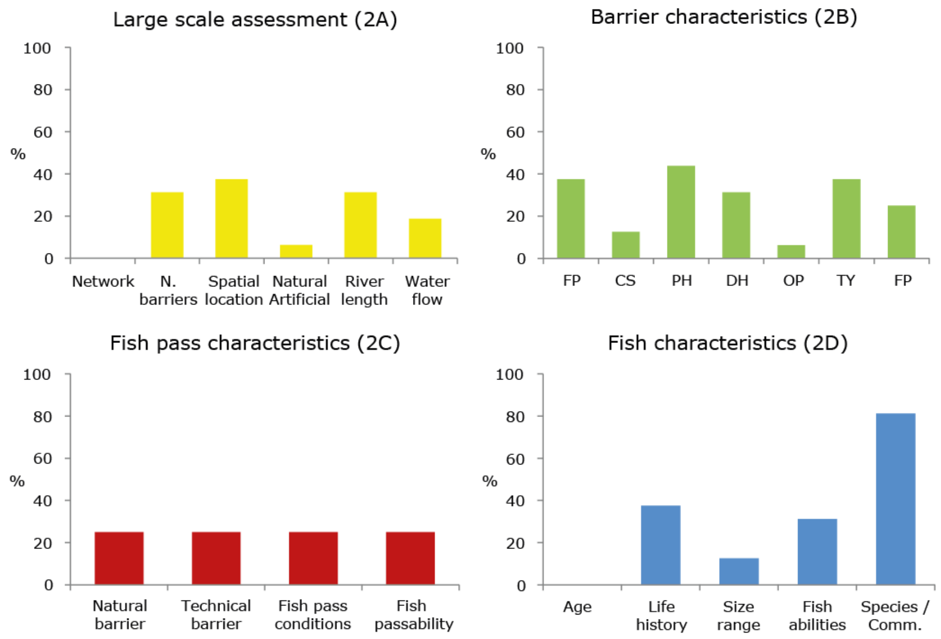

Figure 23 Features collected by European methods for the assessment of longitudinal continuity for fish communities (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Barrier characteristics: FP, flow parameters, CS, cross-section topography, PH, physical attributes; DH, inflow/outflow drop height; OP, presence of an outflow pool; TY, type of barrier; FP, presence of a fish pass

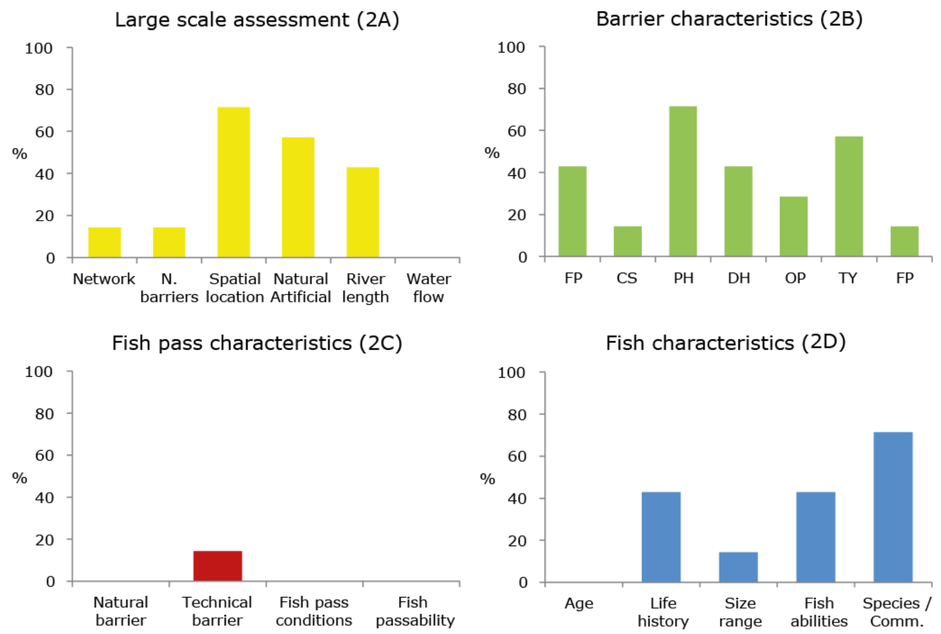

Figure 24 Features collected by non-European methods for the assessment of longitudinal continuity for fish communities (numbers in brackets refer to table entries). Data are shown as a percentage of methods that collect/record/assess a given characteristic. Note that the total percentage is not necessarily equal to 100%, given that each method could be associated with more than one characteristic (table entry) or none. Barrier characteristics: FP, flow parameters, CS, cross-section topography, PH, physical attributes; DH, inflow/outflow drop height; OP, presence of an outflow pool; TY, type of barrier; FP, presence of a fish pass

2.6 Methods implemented by EU countries for the WFD

In this section we overview the assessment methods which are commonly used and/or have been formally approved for the implementation of the WFD in each EU country. We reviewed 21 methods in total. Given that parts of these methods are only published in the national language, this review is mainly limited to those methods for which some information in English was available (papers, English summaries, etc.).

Table 22 lists the 21 EU methods that were reviewed and their key references. The reviewed methods are summarized in Appendix D and Appendix E. In Appendix D a short definition of table entries is reported, while Appendix E includes a summary descriptive table for each method. The description of each method is provided in 5 sections:

1. Method background: provides the main information (name, country, references, etc.) and scope of the method.
2. Method characteristics: reports some general information and characteristics of the method (e.g. survey strategy, spatial and temporal scales of application, etc.).
3. Recorded features: reports some examples of features collected by the method for the different portions of the river corridor (channel, riparian zone, floodplain).
4. River processes: provides information on river processes considered by methods.
5. Application to WFD: discusses strengths and applications of the method for the WFD and river management.

In the summary tables, the term "Not applicable" is used when the method does not assess/consider the selected feature, while "Not available" is used when it was not possible to get that information.

In this section, a comparative analysis of the selected methods used for the implementation of the WFD by the European countries is reported for each of the 5 categories of information (Table 23). A summary of knowledge gaps and recommendations for future developments is reported in the section 4.6.

Table 22 Summary of reviewed EU methods and references (methods implemented for the WFD)

Country	Name of the method	Key references	Type of assessment
Austria	Gudelines for assessing the hydromorphological status of running waters	Mühlmann (2010)	Physical habitat assessment
Czech Republic	HEM - Hydroecological Monitoring method	Langhammer (2007)	Morphological assessment
Denmark	DHQI - Danish Habitat Quality Index	Pedersen & Baattrup-Pedersen (2003)	Physical habitat assessment
England & Wales	RHS - River Habitat Survey	Raven et al. (1997 and following)	Physical habitat assessment
France	CarHyCe – Hydromorphological characterization of rivers	ONEMA (2010)	Physical habitat assessment
France	SYRAH-CE & AURAH-CE – Hydromorphology auditing	Chandesris et al. (2008); Valette et al. (2010)	Morphological assessment
France	ROE – National database on barriers to flow continuity & ICE - Information on ecological continuity	ONEMA (2010)	Longitudinal continuity for fish assessment
Germany	LAWA-FS - Stream habitat survey - field survey method	LAWA (2000, 2002a)	Physical habitat assessment
Germany	LAWA-OS - Stream habitat survey - overview survey method	LAWA (2002b)	Physical habitat assessment
Ireland	RHAT - River Hydromorphology Assessment Technique	Murphy & Toland (2012)	Physical habitat assessment
Italy	CARAVAGGIO - Core assessment of river habitat value and hydro-morphological conditions	Buffagni et al. (2005)	Physical habitat assessment
Italy	MQI - Morphological Quality Index	Rinaldi et al. (2013)	Morphological assessment
Latvia	Methodology for the assessment of Hydromorphological changes	Sigita Šulca (2012) (PPT)	Morphological assessment
Netherlands	Handboek HYMO - Manual for hydromorphology	Dam et al. (2007)	
Poland	MHR - River Hydromorphological Monitoring	Ilnicki et al. (2009)	Physical habitat assessment
Portugal	Adaptation of RHS	Ferreira et al. (2011)	Physical habitat assessment
Scotland	MImAS - Morphological Impact Assessment System	UKTAG (2008)	Morphological assessment
Slovakia	Hydromorphological Assessment Protocol for the Slovak Republic	NERI & SHMI (2004); Lehotský & Grešková (2007)	Physical habitat assessment
Slovenia	Indices for assessment of hymo alteration of rivers	Tavzes & Urbanic (2009)	
Spain	IHF - Index for the assessment of fluvial habitat in Mediterranean rivers	Pardo et al. (2002)	Physical habitat assessment
Spain	QBR - Riparian Forest Quality Index	Munné & Prat (1998)	Riparian habitat assessment

Table 23 Summary of analyzed methods characteristics according to the 5 sections of analysis

1 - METHOD BACKGROUND			Specific to each method (Appendix E)
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	More than 80%; several purposes. The use of maps prevails
		Field survey	Almost all methods
		Rapid field assessment	Small part of methods (e.g. DHQI, IHF, AURAH-CE). For some methods rapid assessment is carried out by trained surveyors (e.g. QBR, RHS)
		Existing database	Almost 80% of methods. The use of hydrological data and data on river/land management prevails. The SYRAH-CE and ROE are entirely based on existing databases (and maps)
		Modelling	Less than 20% of methods (e.g. ICE, RHAT, Handboek HYMO)
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Several approaches
	LONGITUDINAL SPATIAL SCALE	Fixed length	More than 40% of methods (RHS approach-based and RHS adaptations)
		Scaled to channel width	About 25% of methods (e.g. HEM, CarHyCE, AURAH-CE, HAP-SR)
		Variable length	Almost 40% of methods. Several approaches: homogenous reaches (e.g. IQM, IHF); all water body (e.g. MHR); depending on features assessed (e.g. ICE)
	LATERAL SPATIAL SCALE	Channel	100% of methods
		Banks/Riparian zones	Several methods (90%)
		Floodplain	Most part of methods (80%)
C - TEMPORAL SCALE		Physical and morphological assessment	The characterization/assessment of present conditions prevails
		Hydrological assessment	Few methods (e.g. Handboek HYMO, MHR)
D - TYPE OF METHOD		Characterization/classification	80% of methods; several approaches
		Assessment by index	80% of methods uses a qualitative assessment (index and/or score) of river conditions into 5 (the most part) or 7 (e.g. LAWA) quality classes
		Deviation from reference	Most part of methods making a qualitative assessment
		General assessment / Design framework	Only a lower proportion of methods applies a general assessment approach (e.g. environmental risk assessment of SYRAH-CE and MImAS)
		Modelling status / Scenario	Few methods (e.g. RHS) allow to support habitat models. MImAS models the risk of deterioration as consequence of morphological changes (interventions)
		Final expert judgment	It enters several times in the assessment: 1) to define thresholds between classes (e.g. MQI); 2) to cross-check results of the assessment (LAWA-FS); 3) to directly assess some local features (e.g. the flood risk across floodplain, LAWA-OS); 4) to define reference conditions (e.g. the IHF)
		Links with other systems	Direct link (e.g. National Monitoring Programme, DSHI; the IQH for the Caravaggio; the MQI and the IDRAIM protocol). Not direct link (e.g. RHS and RIVPACS; the French methods; the Spanish methods)
E - REFERENCE CONDITIONS			Several approaches: theoretical (e.g. HEM, SIHM, CarHyCE, MQI); empirical (e.g. RHS); historical (e.g. IHF in Spain, HAP in Slovakia, MHR in Poland); modelled (e.g. RHAT), or a combination of approaches (the German "Leitbild"). Some methods do not consider reference conditions (e.g. the French methods, the Scottish MImAS)
F - GENERAL INFO	RIVER TYPOLOGY		Methods to define river typology differ between countries. River typology could be defined a priori (e.g. MHR, LAWA) or specifically for the scopes of the assessment method (e.g. MQI)
	TYPOLOGY LIMITATIONS		Typology limitations are specific for each method and country: for e.g. Spanish methods apply mostly to Mediterranean rivers; northern Europe methods are often limited to low energy systems (e.g. DHQI); only the Spanish IHF apparently is applicable to temporary streams

	TYPE-SPECIFIC (Protocol / Assessment method)		Only some methods provide specific protocols (e.g. MQI for mountain and lowland streams; LAWA for small and large rivers; MImAS selects attributes and assesses sensitivity according to specific river types)
	BASIS FOR STANDARDS / THRESHOLDS		Each method uses a specific approach
	REACH SCALE SURVEY STRATEGY		Different approaches: 1) equally spaced stretches (e.g. RHS); 2) equally spaced transects (e.g. CarHYCE, Handboek HYMO); 3) selected point features (e.g. ICE); 4) the overall selected reach length (e.g. DHQI, HEM, MQI)
	TIMING AND FREQUENCY		Some few methods give indications on the duration and frequency of the survey (e.g. Handboek HYMO, RHAT)
	DATA PRESENTATION (OUTPUT/LAYOUT)		Colour-based maps represents the most common output. Data collected through the classification/characterization protocol are useful for other purposes (i.e. Databases and/or GIS server, e.g. ROE, LAWA, RHS, Caravaggio, DHQI)
	METHOD SUPPORT / APPLICATION TOOLS		Several cases
	SPATIAL COMPARISON		In general, in each country the spatial comparison is possible for the same river type. RHS database allows for comparison between countries which apply the method
	CONNECTION TO ECOLOGY		The most part of methods allows direct (e.g. the assessment of barrier to longitudinal migration) or indirect (e.g. by recording the presence of barrier to longitudinal continuity) connection to ecology
	USERS		The most part of method allows a wide use of the results (managers, scientists). The most part of methods is recommended to be applied only by trained surveyors
	SCALE INFORMATION		The most part of methods collects data at both large and local spatial scales, where large spatial scale information is provided mainly to make a general river characterization
	NUMBER OF END PARAMETERS		It differs considerably between methods: categories, parameters, sub-parameters, indicators. They are qualitatively (scored), quantitatively (measured) or semi-quantitatively (presence/absence) assessed
3. RECORDED FEATURES			
A – CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Collected by almost 80% of methods
	HYDROLOGICAL REGIME	Hydrological conditions	The evaluation of hydrological condition at the time of the survey prevails. Some other methods make an estimation of hydrological alteration (e.g. MQI), or the risk of alteration (e.g. SYRAH-CE)
		Metrics of hydrological regime	Collected by less than 30% of methods: e.g. annual discharge values (e.g. MHR), discharge and water level fluctuations (e.g. Handboek HYMO)
		Hydro-peaking	Few methods (e.g. SYRAH, Caravaggio)
	VALLEY FORM / FEATURES		Valley form (almost 60% of methods)
B - CHANNEL	CHANNEL PATTERN / PLANFORM		76% of methods. Channel pattern: e.g. braided, meandering, straight (HEM, LAWA-FS). Channel planform: e.g. channel sinuosity, braiding index (Handboek HYMO, SYRAH-CE/AURAH-CE, MQI)
	CHANNEL FORMS		76% of methods. Several approaches
	BED CONFIGURATION		76% of methods (e.g. riffles, pools, runs)
	CHANNEL DIMENSIONS		The most part of methods (80%)
	FLOW-TYPE		More than 40% of methods
	PHYSICAL / HYDRAULIC VARIABLES		Flow velocity (Handboeck HYMO); stream power (CarHyCE)
	SUBSTRATE		Almost all methods (i.e. substrate type and size)
	IN-CHANNEL VEGETATION		Almost 60% of methods
	WOODY DEBRIS		76% of methods
	ARTIFICIAL FEATURES AND STRUCTURES		90% of methods
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		The most part of methods (80%)
	BANK MATERIAL		Less than 40%
	RIPARIAN VEGETATION STRUCTURE		76% of methods
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		71% of methods

	RIPARIAN VEGETATION WIDTH		Less than 50% of methods
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		More than 70%
	ARTIFICIAL FEATURES AND STRUCTURES		90% of methods
	LAND USE		Less than 70% of methods
D – FLOODPL.	FLUVIAL FORMS		About 60% of methods
	INFO ON FLOODPLAIN FEATURES		Almost 20% of methods
	LAND USE		76% of methods
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Mainly indirectly provided (presence of transversal structures). 90% of methods
		Water flow	Mainly indirectly provided (presence of transversal structures). 80% of methods
B - LATERAL CONTINUITY		Lateral hydraulic continuity	85% of methods. Several approaches, mainly by using an indirect one (i.e. presence of longitudinal structures)
		Sediment (and wood) lateral continuity	It concerns less than 70% of methods. Directly (e.g. MQI, HAP) or indirectly (e.g. DHQI, RHS)
C - BANK EROSION / STABILITY			Almost 76% of methods
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	Almost 40% of methods (i.e. HEM, RHAT, MQI, Handboek HYMO, HAP)
		Vertical	Less than 40% of methods (i.e. AURAH-CE, MQI, partially the Caravaggio)
F - VERTICAL CONTINUITY		Groundwater connection	More than 50% of methods (i.e. water abstraction, general hydrological regime alteration)
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			Several approaches (see Table 24)
APPLICATION TO ALL WATER BODIES			The most part of methods applies to all water bodies in the countries where it is used. Not all methods apply to HMWBs and AWBs
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			The most part of methods has been developed to support the definition of good and high status according to the WFD; the most part of methods could also been applied to other status classes (smaller proportion applies to HMWBs and AWBs)
USED TO PREDICT RISK OF DETERIORATION			Only the MImAS has been specifically developed to predict the risk of deterioration; the SYRAH identify zones at risk of deterioration (for several impacts). The Latvian methodology aims to assess the significance, due to human impact, of hymo changes on RBDP. The most part of the other methods could potentially be employed for this purpose
USED TO IDENTIFY IMPROVEMENT TARGETS			85% of methods could at least potentially be used for this purpose
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			Almost 50% of methods could be able to identify cause of ecological impacts (at least for fish longitudinal continuity). Some methods are specifically used to identify causes of the failure in achievement of the good/high ecological status (i.e. MImAS, RHAT, HEM)
KEY STRENGTHS FOR RIVER MANAGEMENT			Each method has specific strength for water management

2.6.1 Methods background

The approach and aims of most of the reviewed European methods are similar: physical habitat assessment is the prevailing type of evaluation (Figure 25). Given that these methods are used for the WFD implementation, they usually follow the CEN standards (2002).
Most countries use a single (physical habitat assessment) procedure for overall hydromorphological evaluation. Only France has developed a set of hydromorphological methods to evaluate separately specific hydromorphological components (CarHyCE, ROE and ICE, Sirah-CE and AURAH-CE). A similar effort has been recently made in Spain (IHF, QBR, HIDRI protocol), and in Italy (Caravaggio, MQI, IARI). More often, the methods combine several hydromorphological objectives by using an integrative approach. This is the case of the SIHM in Slovenia, where a morphological and hydrological modification assessment is combined with an overall physical habitat assessment and biological sampling.
Concerning category 3 (hydrological regime alteration), only the IARI (Italy) provides this kind of assessment. Given that it strongly differs from the other kinds of assessment methods, it is not suitable for a comparative analysis, therefore, it is not included in the summary provided in Appendix E.

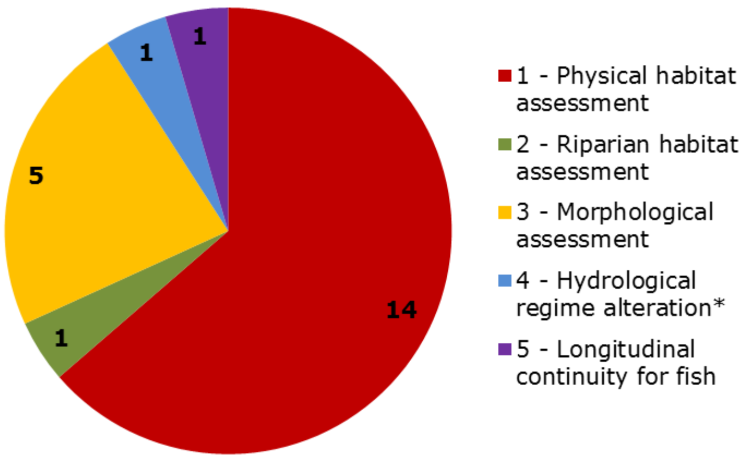

Figure 25 Sum of the number of analyzed methods for each of the 5 categories of assessment methods. (*) The hydrological regime alteration assessment is provided only by the IARI (Italy), which deeply differs from others categories of assessment methods; its description is not reported in the summary tables (Appendix E)

2.6.2 Method characteristics

Most methods make use of maps and/or remote sensing techniques in the assessment protocol, although with different purposes, including the following:

- to compare the present and the historical state (e.g. HEM, MQI, Handboek HYMO);
- to characterize the survey site (e.g. DHQI, Caravaggio, BiotopMap in Sweden);

- to support the selection of the assessed reaches (e.g. MQI, HAP, IHF);
- to make a large scale database inventory and eventually support/plan further field analysis (e.g. SYRAH-CE and ROE, RHAT, Handboek HYMO, RHS in Portugal);
- to carry out a large scale assessment (e.g. LAWA-OS, MHR, SIHM);
- to support the identification/definition of reference status (e.g. HAP).

All methods include a field component as part of the assessment for various aims, such as to verify (e.g. MHR) or survey (e.g. RHS) the presence/absence of selected river features; to measure specific river characteristics (e.g. AURAH-CE in France, Handboek HYMO); to qualitatively evaluate some component of the assessment (e.g. HAP). However, only a few methods adopt a rapid field assessment protocol (e.g. the Danish DHQI, the Spanish IHF). Most methods also use data from existing databases (e.g. HEM: hydrological series to assess hydrological changes; RHS: databases on reference sites; SYRAH-CE and ROE: data on land and river management; MQI: databases on existing artificial intervention; RHAT: information on restoration activities). A modelling approach is less commonly used, but there are some examples: Handboek HYMO uses models to calculate hydrological parameters in ungauged sites; RHAT uses a typology prediction tool (COMPASS) to predict river typology from river characters (e.g. sinuosity); ICE uses a modelled decision tree to support the barrier passability assessment.

Few methods use a hierarchical spatial scale approach. The spatial scale of application ranges from the reach scale (e.g. survey units into sub-survey units, HAP) to the catchment scale (e.g. Handboek HYMO records data to reach, water body and catchment scale). Often larger scale data (catchment, water body) are used to help in defining or assessing reaches at smaller scales (e.g. top-down hierarchical approach, SYRAH-CE and AURAH-CE), while a down-up approach is less frequently used (e.g. HEM).

The selection of the longitudinal spatial scale (survey site/reach) divides the methods into two main groups: (1) those applying the assessment to a defined length (e.g. RHS and following adaptations); and (2) those which define homogenous morphological reaches with variable length (e.g. MQI, SYRAH-CE). Approximately 25% of methods define reach lengths proportional to channel width, and these often correspond to methods which involve field measurements (e.g. CarHyCE and AURAH-CE).

Concerning the spatial context, all methods focus on the river channel, most also include banks and riparian areas, and almost 80% also investigate floodplain features.

All methods aim to characterize or assess the present hydromorphological state of rivers. Several methods collect information (i.e. historical data, maps, photos) useful to understanding changes of status compared to past conditions (e.g. evidence of channel evolution, RHAT), while some methods define past conditions as the reference conditions (e.g. MHR). Only a few methods (MQI, HAP) incorporate historical changes in their assessment. Temporal changes in the hydrological regime are rarely considered (e.g. MHR).

Most methods collect information with the aim of achieving a hydromorphological characterization (i.e. inventorying, mapping). Often the collected information allows for the construction of robust databases (e.g. RHS in England and Wales, LAWA in Germany and CarHyCE). Apart some exceptions (e.g. SYRAH-CE, AURAH-CE, CarHyCE), the collected data are used to obtain a final quality index or score of river conditions according to 5 quality classes. Quality classes are generally defined by comparing the hydromorphological status to a reference condition. A few methods assign a score to some of the features directly in the field (e.g. QBR, MQI). Expert opinion frequently enters in various steps of the assessment process, and not only to define the final conditions (Table 23).

As we noted above, most methods explicitly make use of some reference condition. However, a large variety of definitions of reference condition are used, including:

- theoretical undisturbed conditions, in terms of flow regime, longitudinal continuity and river components (e.g. HEM in Czech Republic);
- based on empirical data obtained from reference sites in the absence of human impact (e.g. RHS);
- historical conditions before the occurrence of human impact (e.g. IHF in Spain, HAP in Slovakia, MHR in Poland)
- theoretical conditions with no water pollution and/or low modifications (e.g. SIHM, CarHyCE);
- theoretical conditions in terms of maximum functionality, minimum artificiality and channel adjustments (e.g. MQI);
- modelled conditions based on river type (e.g. RHAT in Northern Ireland and Republic of Ireland);
- the use of the 'Leitbild' concept (e.g. LAWA), corresponding to the equilibrium state that would develop under the present natural setting without further human intrusions.

Almost every country uses a specific methodology to define river typology; the definition could be part of the assessment protocol (e.g. MQI) or not (e.g. MHR). Methods are often applicable only to the country and/or the range of river typologies for which the method has been developed (Table 23). Only a few methods provide a protocol for specific river types (e.g. MQI for mountain and lowland streams; LAWA for small and large rivers).

At the reach scale, some methods follow a specific reach survey strategy, by collecting data at equally spaced transects (e.g. CarHYCE, Handboek HYMO), or at selected point features (e.g. ICE). In other methods, the assessment is extended to the overall selected reach length (e.g. DHQI, HEM, MQI, MImAS) and in some cases both approaches are used (e.g. RHS).

All methods have at least an indirect (not explicit) connection to ecology, because they provide information on physical habitat quality, availability and continuity. Some of them in part collect physical habitat data directly linked to

ecology (e.g. shading, organic substrate). Moreover some methods have been tested on biological indicators to verify their prediction skill (e.g. IHF, SIHM). In some cases, the hydromorphological assessment is weighted by considering its relevance for ecological components (e.g. Romania, LAWA).
The number of collected/assessed parameters differs considerably between methods. The assessment is often organised into a sort of hierarchical system: parameters are grouped in some main categories (often related to the different portions of the river corridor, i.e. channel, riparian zones, floodplain) which include a certain number of indicators and/or sub-parameters. Some parameters can be qualitatively assessed, or are evaluated by their presence/absence, or by measuring them and quantitatively assessing them.

2.6.3 Recorded features

Concerning the collected features (Table 23), large scale characteristics are considered by 80% of methods, even though they do not enter in the assessment procedure, but are more often used for a general characterization of the river or the reach. Less than 30% of methods incorporate data on hydrological regime, whereas most simply record hydrological conditions at the time of the survey, either qualitatively (e.g. RHS) or quantitatively (e.g. CarHyCE). Only a few methods take into account the presence of hydropeaking (e.g. SYRAH-CE, Caravaggio).
Concerning the channel features, 76% of methods classify the present channel pattern either qualitatively (e.g. HEM, LAWA-FS) or quantitatively (e.g. Handboek HYMO, SYRAH-CE/AURAH-CE, MQI). Channel forms (i.e. bars, islands) are also considered by 76% of methods: they record (e.g. RHS and following developments) or assess (e.g. MQI) the presence/absence of channel forms or evaluate channel features such as cross section variability (e.g. HEM) or naturalness (e.g. MHR). More than 80% of methods record channel dimensions, corresponding mainly to cross section measurements (i.e. bankfull/channel widths), or variability assessments (e.g. width variations, cross section variability). More than the 40% of the methods considers the flow types, and only two methods directly measure some physical variables, such as flow velocity (Handboeck HYMO) and stream power (CarHyCE). Almost all methods consider bed substrate characteristics, mainly in terms of substrate type and size, including variability or diversity. Most methods evaluate in-channel artificial features, in terms of their impact on longitudinal river continuity (transversal structures), bed modifications (artificial bed revetments) and as consequence in terms of habitat diversity or reduction and river functioning.
Concerning river bank features, almost 80% of methods record and/or assess bank profile and shape. In contrast to the channel substrate, there is limited consideration of bank materials (less than 50% of methods). Concerning the riparian zone, riparian structure (i.e. herbs, shrubs, trees) and longitudinal continuity are assessed by about 70% of methods, whereas the riparian vegetation width is assessed by only 50%. Most methods also consider the

vegetation composition, especially the presence of exotic species in comparison with endemic ones. Most methods take account of impacts from artificial structures (90%) on banks and riparian areas (e.g. bank stabilisation structures), and 75% also consider the land use in the riparian zone.
Concerning the floodplain, methods collect data mainly on land use (85%) and fluvial forms (about the 60%, providing information on lateral connectivity).

2.6.4 River processes

As noted above, most methods provide some information on the presence and location of transversal structures (e.g. ROE and ICE, HAP, etc.), and therefore indirectly on the longitudinal continuity of water, sediments and matter (woody debris, organisms). Similarly, many methods evaluate the present conditions of lateral hydraulic connectivity (85%), whereas less than 70% provide some direct (i.e. MQI, HAP) or indirect (i.e. DHQI, RHS) information on lateral sediment connectivity between the river and its floodplain. In particular, large scale sediment connectivity is poorly assessed (i.e. SYRAH-CE, RHAT). More than 75% of methods assess bank erosion and stability, mostly indirectly and qualitatively (e.g. evidence of bank erosion, bank protection structures).
Given that most of the methods focus on physical habitat, river processes related to channel adjustments are poorly assessed. Some limited effort is made concerning planform changes (i.e. HEM, RHAT, MQI, Handboek HYMO, HAP). Even more infrequent is the assessment of vertical changes, where the few exceptions are represented by the AURAH-CE, the MQI, and partially by the Caravaggio (it records signs of river incision). Similarly, processes related to vertical continuity (relations between river and groundwater) are only indirectly assessed (e.g. water abstraction, general hydrological regime alteration are assessed in 52% of methods).

2.6.5 Application to WFD

In Table 24 we listed the methods adopted in each European country for the implementation of the WFD, and indicated their status of application. We also included, when available, supplementary information concerning the hydromorphological assessment for those countries that do not employ a specific method (e.g. BiotopeMap in Sweden), or because the adopted method refers to some particular objective related to hydromorphology (e.g. the criteria applied in Romania for HMWBs).
Most analyzed methods have been developed to satisfy WFD requirements, even though not all the reviewed methods have been formally selected as compulsory for the hydromorphological assessment of rivers (Table 24). The following methods are those formally selected by European countries for implementation of the WFD: HEM (Czech Republic), DHQI (Denmark), CarHyCE (France), MQI, Caravaggio and IARI (Italy), MHR (Poland), SIHM (Slovenia). In addition, the Latvian methodology is officially used for the definition of hydromorphological

changes in RBDP (Rural Business Development Project), and the Criteria used to define HMWBs in Romania are also those officially used by the Water Authority. In Austria, the guidelines for the assessment of hydromorphology have been developed and published by the Federal Ministry of Agriculture and Forestry (*Bundesministerium* für *Land- und Forstwirtschaft)*, but to date they have rarely been used.

Methods generally support the classification of all levels of ecological status even though the WFD strictly requires that the hydromorphological status is needed only to support the definition of good and high ecological status (Table 23). Moreover, methods which assess the impact of artificial features can potentially or indirectly be used to predict risk of deterioration, but only few methods directly do this (e.g. MImAS, SYRAH-CE; Table 23).

Almost all methods can potentially be employed in the identification of improvement targets (e.g. LAWA-FS), as well to help in identifying causes of ecological impacts (e.g. the IHF), and especially for the assessment of the impact of the alteration of longitudinal continuity (i.e. barrier to migration).

Concerning the strengths of the methods for water management, methods differ greatly and each one has specific peculiarities. Low subjectivity is a property only of those methods based on direct feature measures (e.g. CarHyce), but these require greater effort and time for their application. In contrast, rapid field assessment protocols (e.g. DHSI) are quicker, but their subjectivity is higher. Some other methods are highly repeatable and flexible (e.g. SYRAH-CE, RHAT). Several methods focus on habitat assessment and are more related to biology, whereas others are more process-oriented, accounting for temporal morphological changes, so that they can be used more effectively for understanding impacts and causes of morphological alteration (e.g. MQI).

Table 24 Census of hydromorphological methods and/or assessment criteria applied in each European country for the implementation of the WFD (NA = information not available)

Official method for the WFD for EU countries

Country	Method/s	Key reference	Status concerning the WFD
Austria	Guidelines for assessing the hydromorphological status of running waters	Mühlmann (2010)	It is the official method for the assessment of hymo conditions to support the ecological status assessment (WFD)
Belgium	NA		NA
Bulgaria	NA		NA
Cyprus	NA		NA
Czech Republic	HEM	Langhammer (2007; 2008)	Recommended by the Ministry of Environment
Denmark	DSHI	Pedersen & Baattrup-Pedersen (2003)	Officially used in the National Monitoring programme; recommended by authors
England and Wales	RHS	Raven et al. (2007)	Most commonly used in England and Wales since 2000s
Estonia	NA		It seems there is any official method but only a proposal (NA)
Finland	NA		NA
France	CarHyCE; Syrah & Aurah-CE; ROE & ICE	Onema (2010); Chandesris et al. (2008); Valette et al. (2010)	CarHyCE will be used as the official one; SYRAH-CE, AURAH-CE, ROE and ICE have been developed to comply WFD requirements
Germany	LAWA-FS; LAWA-OS	LAWA (2000, 2000a; 2002b)	LAWA-FS is the most commonly used (but not formally selected); LAWA-OS has been nationally accepted in the 1st 'River Basin District Analysis 2004"
Greece	NA		NA
Hungary	NA		NA
North. Ireland; Rep. of Ireland	RHAT	Murphy & Toland (2012)	It has been developed specifically for WFD compliance
Italy	MQI; IARI; CARAVAGGIO	Rinaldi et al. (2013); Bussettini et al. (2011); Buffagni et al. (2005)	MQI, IARI and CARAVAGGIO for the overall hydromorphological assessment; CARAVAGGO for the reference sites
Latvia	Method for assess Hymo changes	Sigita Šulca (2012) (PPT)	Nationally used in the definition of hydromorphological changes in RBDP (River Basin District Projects)
Lithuania	NA		NA
Luxembourg	NA		NA
Malta	No national method established		No national method established
The Netherlands	Handboek HYMO	Dam et al. (2007)	It allows to monitor and analyze hymo quality elements. It has not been officially selected
Poland	MHR	Ilnicki et al. (2009; 2010a, b)	It is officially approved for the hydromorphological assessment of rivers in Poland
Portugal	Adaptation of RHS (Ferreira et al., 2011)	Ferreira et al. (2011)	It has been developed in accordance with the WFD and with a work plan defined by Portuguese Water Authorities to achieve the fluvial hydromorphological characterization and assessment
Romania	Criteria and parameters for assessment of HyMo significant pressures and designation of HMWB		For the designation of HMWBs

Scotland	MImAS	UKTAG (2008)	It is a proposal tool to support the assessment and montoring of the ecological status (morphological alteration and risk) of rivers
Slovakia	HAP-SR	NERI & SHMI (2004); Lehotský & Grešková (2007)	It is the proposed method for the definition of ecological status of rivers in the Slovak Republic
Slovenia	SIHM	Tavzes & Urbanic (2009)	It is the national method for the application of the WFD
Spain	IHF; QBR	Pardo et al. (2002); Munné & Prat (1998)	Both methods are widely used by Water Agencies for the hydromorphological assessment for the WFD
Sweden	Assessment criteria for hydromorphological quality elements; BiotopeMap	SEPA (2007); Hallde'n et al. (2002)	Criteria for the assessment of the hydromorphological quality elements to support the good and high ecological status. The BiotopeMap is the most common field method to collect/inventory environmental variables

2.7 Other tools for physical habitat assessment

This section briefly reviews other tools, methods, and indicators that are used for a more detailed characterization, monitoring and analysis of physical habitats and morphological units (methods for an overall geomorphological and/or hydrological analysis are not included). These tools are generally applied to specific sites or reaches and are often aimed at designing and/or monitoring river restoration interventions.

2.7.1 Characterization, mapping and measuring of physical habitats

This category includes methods for field and/or remote sensing mapping, GIS analysis, measurement of variables and indicators of physical habitats.
Table 25 shows examples of mapping methods, tools, indicators, variables and applications used to support the assessment and characterization of physical habitats.

2.7.2 Modelling tools

This section includes a brief review of physical habitat modelling. Models which focus on physical habitats can be divided based on their scale of interest: Micro versus Mesohabitat models. Moreover models can include univariate or multivariate analysis, considering several parameters.
Most models assess and/or consider the 3 following parameters: velocity, depth and substrate. Examples of other assessed parameters are: Froude number, shear stress, shelter (cover), presence of organic matter, vegetation, wood, flow vorticity.
The Table 26 shows examples of the most widely used models in the characterization of physical habitats of rivers and streams.
Further approaches that can provide recommendations for the maintenance or restoration of physical habitats are the holistic methodologies used for the environmental flow assessment ("Eflows"). These methods are distinguished from the previous single purpose modelling tools because they aim to assess the flow requirements of the many interacting components of aquatic systems (Arthington, 1998; King et al., 2008; Navarro & Schmidt, 2012). The Eflows concept is close to the environmental objectives of the WFD directive, which requires that the flow regime should provide conditions "consistent with the achievement of the values specified for the Biological Quality Elements". It has been estimated that some 200 different generic methods have been developed to derive 'environmental flows' (Tharme, 2003; Arthington et al. 2006). The differences among the various methods depend on the purposes of application, the specific characteristics of the case study, and the type of issue to be addressed (water planning, monitoring, river restoration plan, etc.).
A comprehensive review of this category of approaches and methods is reported in Arthington (1998), King et al. (2008), and Navarro & Schmidt (2012).

Table 25 Examples of mapping methods, tools, and indicators to support the hydromorphological assessment and characterization of rivers and streams

Mapping physical habitats and/or hydromorphological state				
Tools/Methods/Indicators name	**Key Reference**	**Measures/Variables/Parameters**	**Methods**	**Spatial scale**
IAM (Indice d'Actractivité Morphodynamique)	Degiorgi et al. (2002)	Water flow, substrate (mineral and organic), water depth --> cartography + index	Field analysis/mapping	Measurements at transects; morphological units
Hydromorphological units (HMU = Mesohabitat) classification and evolution	Alcaraz-Hernandez et al. (2011)	Length, width, average and maximum depth, percentage of substrate and water volume --> habitat classification and evolution	Field analysis/mapping	Reach scale; river reaches comparison
Salmonid Spawning Habitat Availability (SHA) Survey	Schuett-Hames et al. (1999)	Substrate particle size, substrate depth, water depth, water velocity, and surface area coverage	Field analysis/mapping	Sub-reach scale; local scale; transect and patch measurement methods
LWD survey	Macka et al. (2011)	Physical attributes of LWD (diameter, length, mass, etc.); spatial attributes (localisation in the network/in the channel, orientation vs. flow, morphological effects, etc.); ecosystem attributes (carbon content, decay status, habitats, etc.)	Field surveys and mapping	Reach scale; sub-reach scale; local scale
Mapping topographic/morphological units	Gilvear et al. (2004)	Habitat mapping: in-channel (shallow/deep water) and floodplain (bars, islands, several classes of riparian vegetation) habitats, artificial features	Remote sensing: colour aerial images and multi-spectral airborne images, field verifications	Reach scale
	Johansen et al. (2007)	Vegetation measurements (from veg. index): % canopy cover, organic litter, canopy continuity, tree clearing. Mapping of land-cover types (morphological units): water body, riparian veg., exposed banks, bare areas + Measurement of riparian zone parameters: riparian width, vegetation width, bank stability, flood damage + Vegetation assessment (comparison with health indicators from a field protocol method, TRARC)	Remote sensing: satellite images (QuickBird) and techniques (Spectral Vegetation Indices - SVIs: NDVI, EVI, SAVI; supervised image classification), field verifications	Reach scale
DEM-derived analysis	Bertoldi et al. (2011)	Characterize the topography: vegetation structure, height, density; channel gradient; bank and bar height, etc.; relation between morphological units and vegetation	Remote sensing: LiDAR, grid DEM (50 m resolution)	Reach scale; sub-reach scale
	Ferencevic & Ashmore (2011)	Stream power extraction from DEM (modelling methods) and distribution on maps	Remote sensing: DEM (10m resolution)	Stream network
Mapping physical habitat dynamic	Boruah et al. (2008)	Extent and pattern of: low flow channels, vegetated	Combination of remote	River scale

(vegetation and/or physical processes, and in relation to drivers and impacts)		islands, exposed sand bars, floodplain vegetation	sensing data (Satellite images in the example) & techniques (unsupervised classification)	
	Lejot et al. (2011)	Inventory & characterize fluvial features dynamics: oxbow lakes evolution; monitoring of sediment load input and bathymetric evolution (restoration action); planform evolution	Remote sensing supports & techniques: satellite images (several resolutions & spectral layers), aerial photos, high resolution images, combination to hydrological series/events	Network/catchment scale; reach scale, sub-reach scale; local scale
Acoustic Doppler Current Profilers (ADCP) to characterize aquatic habitats	Rigby (2003)	Velocities vs. time; calculation of vorticity and circulation metrics;	Remote sensing: Acoustic Doppler Current Profilers	Reach scale; sub-reach scale; measurements at transect
Measurement of channel form (cross-section, longitudinal profile, channel planform, sediment size, etc.)	Fitzpatrick et al. (1998); Egozi & Ashmore (2008)	Cross-section, longitudinal profile, channel planform, sediment size, Bank Stability Index, etc.	Field measurements; maps; remote sensing	Reach/river scale; Cross section scale
Measurement of sediment size	Kondolf et al. (2003b)	Sediment size; suspended sediment measurement; clogging; Riffle Stability Index (RSI); measure of substrate depth	Field measurements; remote sensing	Reach/local scale
Measurement of hydrological variables	Gordon et al. (1992); Whiting (2003)	Water discharge, velocity, depth, magnitude, frequency, etc.	Field measurements; Existent data series	Local scale

Table 26 Examples of modelling methods commonly used for the physical habitat characterization of rivers and streams. Some examples of other generic hydrological and morphological methods are also mentioned

Modelling methods (physical habitats)			
Tools/Methods/Indicators name	**Key Reference**	**Measures / Variables / Parameters**	**Type**
Micro-Habitat			
PHABSIM (Physical Habitat Simulations)	Bovee et al. (1998)	Depth, velocity, substrate	1D model, univariate
RHYHABSIM (River Hydraulics and Habitat Simulations)	Jowett (1989)		
CASiMiR	Burke et al. (2009)		1 and 2D model, multivariate
EVHA (Evaluation of Habitats)	Ginot (1995)		
Hydraulic geometry	Lamouroux (2008)	River reach scale; microhabitat scale	
IFIM (Instream Flow Incremental Methodology)	Bovee et al. (1998)	Velocity/depth/substrate preferences for species and their life stages	
Meso-Habitat			
MesoHabsim	Parasiewicz (2001, 2007 and following)	Depth, velocity, substrate, Froude number, presence of organic matter, vegetation, wood, shelter…	Field survey of hydromorphic units at different flow stages, electrofishing, Multivariate logistic analysis
	Vezza et al. (2012)	Chemical properties (Temperature, water pH and oxygen)	
RHASIM (Habitat simulation)	Liefeld and Schulze (2005)	Velocity 2D (water depth, water level); substrate clogging (presence of a sediment layer = suspended matter content, velocity, discharge); water quality (oxygen, phosphate, suspended matter content, transparency); Habitat Simulation module (for each grid cell, for each target species or life stage; based on experiments and field study and international literature)	2D model
MEM (Mesohabitat Evaluation Model)	Hauer et al. (2007 and following)	Water depth, flow velocity, bed shear stress (sediment transport, benthic drift)	
MesoCASiMiR	Schneider et al. (2006)	Water depth, flow velocity, substrate, coverage, habitat fragmentation and connectivity	Fuzzy logic

3. Ecological methods

Ecological status assessment methods are based on a characterisation of different organism groups, comparing current conditions with type-specific reference conditions. Methods are applied at the level of the water body. For rivers, a water body in most cases coincides with the reach scale.
This review covers the methods that are being used by the EU countries to monitor ecological status. We reviewed 91 methods covering fish fauna, macrophytes, benthic diatoms, and benthic invertebrates from 27 European countries.

In the context of the Water Framework Directive implementation and in close collaboration with the research project WISER, descriptions of all ecological assessment methods have been collected for the intercalibration exercise where the classification outcomes were harmonised. Method descriptions are available on the web (Birk et al., 2010) This compilation is used as the main source for the method review in this report. Further information on the WISER method compilation and a summary analysis of the attributes of the methods covering rivers, lakes, coastal and transitional waters are reported in Birk et al. (2012).

3.1 *Assessing ecological status for the Water Framework Directive*

Separate assessment methods are required for four 'biological quality elements' – fish fauna, macrophytes, benthic diatoms, and benthic invertebrates. For each water body, these assessments are combined using the 'one out – all out' rule where the biological quality element with the lowest status determines the final status (Caroni et al, in press).

3.2 *Overview of Methods*

In Tables 27-30 the assessment methods for the different biological quality elements are listed. For each method it is indicated whether it is included in the official intercalibration results (European Commission, in preparation), and whether a description of the method is available in the WISER method compilation (Birk et al., 2010). This overview covers 20 methods for fish, 21 methods for macrophytes, 21 methods for benthic diatoms, and 29 methods for benthic invertebrates. Methods from all EU Member States are covered, except of Malta and Latvia. Additionally, methods from non-EU Member States Norway and Croatia are included.

Table 27 Overview of WFD ecological status river assessment methods (Fish Fauna)

Methods from European countries: Fish Fauna				
Method	**Code**	**Country**	**WISER overview**	**Intercalibration COM Decision**
Fisch Index Austria	FIA-AT	Austria	✓	✓
Biological Index for Fish Integrity	IBIP-BE	Belgium (Wallonia)	✓	✓
Flemish Index of Biotic Integrity	IBI-BE	Belgium (Flanders)	✓	✓
Czech national method of the river ecological status classification according to the fish biocoenosis	CZI-CZ	Czech Republic	✓	✓
Estonian fish-based assessment method	FBA-EE	Estonia	✓	
Finnish Fish Index	FIFI-FI	Finland	✓	✓
Indice Poissons Rivière	IPR-FR	France[1]	✓	✓
FIBS	FIBS-DE	Germany	✓	✓
Ecological Quality Index of Hungarian Riverine Fishes	EQRF-HU	Hungary	✓	
Index of Ecological Status of Fish Communities	IESF-IT	Italy	✓	
Assessment method of rivers using Lithuanian fish index	LZI-LT	Lithuania	✓	✓
Netherlands References and Metrics for Fish	NLFISR-NL	Netherlands	✓	✓
F_IBIP	F_IBIP-PT	Portugal	✓	✓
EFI+ European Fish index	EFI-RO	Romania	✓	✓
Fish Index of Slovakia	FIS-SK	Slovakia	✓	✓
Assessment of fish fauna in rivers	SIFAIR-SI	Slovenia	✓	✓
Index of Biotic Integrity using fish as indicators of the Ecological Status of Catalonian Rivers	IBICAT-ES	Spain (Catalonia)	✓	✓
Spanish Fish Index	IBI-ES	Spain	✓	✓
Environmental quality criteria to determine the status of fish in running waters	VIX-SE	Sweden	✓	✓
Fisheries Classification Scheme 2	FCS2-UK	UK	✓	✓

[1] Also applied in Luxemburg

Table 28 Overview of WFD ecological status river assessment methods (Macrophytes)

Methods from European countries – Macrophytes				
Method	**Code**	**Country**	**WISER overview**	**Intercalibration COM Decision**
Austrian Index Macrophytes for Rivers	AIM-AT	Austria	✓	✓
Flemish macrophyte assessment system	MAFWAT-BE	Belgium (Flanders)	✓	✓
Macrophyte Biological Index for Rivers	IBMR-BE	Belgium (Wallonia)	✓	✓
Methodology for hydrobiological monitoring - Macrophytes	MRI-BU	Bulgaria	✓	✓
Croatian macrophyte assessment method	CMA-HR	Croatia	✓	
Biological Macrophyte Index for Rivers	IBMR-CY	Cyprus Greece	✓[2]	✓
Danish Stream Plant Index	DSPI-DK	Denmark		✓
Combined sampling area and sampling quadrate method	CSQ-EE	Estonia	✓	
Biological Macrophytes Index for Rivers	IBMR-FR	France[3]	✓	✓
German Assessment System for Macrophytes and Phytobenthos according to the EU WFD, Macrophytes Module	DEMP-DE	Germany	✓	✓
Biological Macrophyte Index for Rivers	IBMR-GR	Greece	✓[2]	✓
The Hungarian Macrophyte Guidance	MRI-HU	Hungary	✓	✓
Macrophyte Biological Index for Rivers	IBMR-IT	Italy	✓	✓
Mean Trophic Ranking	MTR-IE	Ireland		✓
WFD-metrics for natural watertype	NLMP-NL	Netherlands	✓	
Macrophyte Index for Rivers	MIR-PL	Poland	✓	✓
Biological Macrophyte Index for Rivers	IBMR-PT	Portugal	✓[2]	✓
Slovak assessment of macrophytes in rivers	BMI-SK	Slovakia	✓	✓
River Macrophyte Index	RMI-SI	Slovenia	✓	✓
Biological Macrophyte Index for Rivers	IBMR-ES	Spain	✓[2]	✓
LEAFPACS	LEAFPACS-UK	UK	✓	✓

[2] IBMR reported in WISER only by Belgium, France, Italy
[3] Also applied in Luxemburg

Table 29 Overview of WFD ecological status river assessment methods (Benthic Diatoms)

Methods from European countries Benthic Diatoms				
Method	**Code**	**Country**	**WISER overview**	**Intercalibration COM Decision**
Assessment of the biological quality elements - part phytobenthos	PB-AT	Austria	✓	✓
Proportions of Impact-Sensitive and Impact-Associated Diatoms (PISIAD)	PISIAD-BE	Belgium (Flanders)	✓	✓
Indice de Polluosensibilité Spécifique	IPS	Belgium (Wallonia) Cyprus Estonia Finland Luxemburg Portugal Spain	✓	✓
Ecological status assessment of rivers in Bulgaria based on IPS diatom index	PB-BG	Bulgaria	✓	✓
Croatian Diatom Trophic Index	CDT-HR	Croatia	✓	
Assessment system for rivers using phytobentho	PB-CZ	Czech Republic	✓	✓
IBD 2007	IBD-FR	France	✓	✓
German Assessment System for Macrophytes and Phytobenthos according to the EU WFD, Phytobenthos Module	PB-DE	Germany	✓	✓
Improvement of the Hungarian ecological water qualification system - Phytobenthos in Rivers	PB-HU	Hungary	✓	✓
Intercalibration Common Metrics Index	ICM-IT	Italy	✓	✓
Revised form of Trophic Diatom Index (TDI	TDI-IE	Ireland	✓	✓
KRW Maatlat	PB-NL	Netherlands	✓	✓
Periphyton Index of Trophic Status (PIT)	PIT-NO	Norway	✓	✓
Indeks Okrzemkowy IO dla rzek (Diatom Index for rivers)	PB-PL	Poland		✓
Assessement Method for Ecological Status of the Water Body (rivers) based on Phytobenthos	PB-RO	Romania	✓	
Slovak assessment of benthic diatoms in rivers	PB-SK	Slovakia	✓	✓
Ecological status assessment system for rivers using phytobenthos	PB-SI	Slovenia	✓	✓
Diatom multimetric (MDIAT)	MDIAT-ES	Spain		✓
Benthic algae in running water - diatom analysis	PB-SE	Sweden	✓	✓
DARLEQ mark 2	DARLEQ-UK	UK		✓
Diatom Assessment for River Ecological Status (DARES)	DARES-UK	UK	✓	✓

Table 30 Overview of WFD ecological status river assessment methods (Benthic Invertebrates)

Methods from European countries: Benthic Invertebrates				
Method	**Code**	**Country**	**WISER overview**	**Intercalibration COM Decision**
Assessment of the biological quality elements - part benthic invertebrates	BI-AT	Austria	✓	✓
Multimetric Macroinvertebrate Index Flanders	MMIF-FL	Belgium (Flanders)	✓	✓
Indice Biotique Global Normalisé	IBGN	Belgium (Wallonia) France Luxemburg	✓	✓
Benthic macroinvertebrates - Methodology and standards for analysis	BI-BG	Bulgaria	✓	
STAR Intercalibration Common Metric Index	ICMi-cy	Cyprus Greece	✓	✓
Assessment system for rivers using macrozoobenthos	BI-HR	Croatia	✓	
Czech system for ecological status assessment of rivers using benthic macroinvertebrates	BI-CZ	Czech Republic	✓	
Danish Stream Fauna Index	DSFI	Denmark Lithuania	✓	✓
Estonian surface water ecological quality assessment – river macroinvertebrates	BI-EE	Estonia	✓	✓
Finnish multimetric index	MMI-FI	Finland	✓	✓
Assessment method for rivers using benthic invertebrates	PERLODES-DE	Germany	✓	✓
Hungarian Multimetric Macroinvertebrate Index	BI-HU	Hungary	✓	✓
MacrOper, based on STAR_ICM index calculation	MO-IT	Italy	✓	✓
Quality Rating System (Q-value)	Q-IE	Ireland	✓	✓
KRW Maatlat	BI-NL	Netherlands	✓	✓
AcidIndex2	AI-NO	Norway		✓
Polish BMWP verified by modified Margalef diversity index	BMWP-PL	Poland	✓	
$RIVECO_{macro}$	RIVECO-PL	Poland		✓
Rivers Biological Quality Assessment Method-Benthic Invertebrates (IPtIN, IPtIS)	BI-PT	Portugal	✓	✓
Assessment method for ecological status of water bodies based on macroinvertebrates	BI-RO	Romania	✓	✓
Slovak assessment of benthic invertebrates in rivers	BI-SK	Slovakia	✓	✓
Ecological status assessment system for rivers using benthic invertebrates	BI-SI	Slovenia	✓	✓
Iberian Biological Monitoring Working Party	IBMWP-ES	Spain	✓	✓
METI (IMMi-T)	METI-ES	Spain	✓	✓
Multimetric Index for Stream Acidity	MISA-SE	Sweden	✓	✓
DJ-Index	DJ-SE	Sweden	✓	✓
Average Score per Taxon	ASPT	Norway Sweden UK	✓	✓
WFD Acid Water Indicator Community specie	AWICsp-UK	UK	✓	✓
River Invertebrate Classification Tool	RICT-UK	UK	✓	✓

3.2.1 Method characteristics and sensitivity to pressures

Fish fauna methods

Table 31 gives an overview of some key characteristics of 20 assessment methods using fish communities applied in 18 European countries. Almost all methods are based on multi-habitat sampling that is undertaken on one single occasion. The number of replicates used to classify a site varies, but is in the majority of cases smaller than five. Most of the methods are multimetric assessment systems, and are dominated by metrics based on species composition. Diversity methods are included in 50% of the fish methods. Although the Water Framework Directive prescribes that age structure should be included in fish assessment, it is only taken into account by 20% the methods.

All fish methods are designed to respond to multiple pressures. Hydromorphological pressures are covered; for 75% of the fish methods it is explicitly reported that they respond to hydromorphological pressures. Habitat alteration is mentioned for 55% of the methods, flow modification for 40% of the methods. River continuity is only mentioned for one single method (CZI-CZ).

In conclusion, the fish assessment methods seem to be suitable to detect the effects of hydromorphological pressure, but they are not very specific.

Macrophytes methods

Table 32 gives an overview of key characteristics of 21 assessment methods using macrophytes applied in 20 European countries. Again, most methods are based on multi-habitat sampling that is undertaken on one single sampling occasion. The number of replicates used to classify a site varies, but is in the majority of cases smaller than five. All methods are multimetric assessment systems, and are dominated by metrics based on species composition. Diversity is included in only 10% of the diatom methods.

As for fish, methods are designed to respond to multiple pressures. Hydromorphological pressures are covered; for 71% of the methods it is explicitly reported that they respond to hydromorphological pressures. Habitat alteration is explicitly mentioned for 62% of the methods, flow modification for 24% of the methods.

In conclusion, the macrophyte assessment methods seem to be suitable to detect the effects of hydromorphological pressures, but they are not very specific.

Benthic diatom methods

Table 33 gives an overview of key characteristics of 21 assessment methods using benthic diatoms applied in 24 European countries. Roughly half of the methods use single-habitat sampling, the other half uses multi-habitat sampling. Assessments are in most cases based on 1-5 sampling occasion. The number of replicates used to classify a site varies, but is in the majority of cases smaller than five. All methods are multimetric assessment systems, and are dominated

by metrics based on species composition. Diversity is included in 19% of the diatom methods.
All diatom methods are designed to respond to pressures related to nutrients and eutrophication. Some methods are also reported to be sensitive to acidification and chemical pollution. Hydromorphological pressures are covered by 24% of the methods, but it can be expected that this mainly applies to indirect effects by the hydromorphological pressures on nutrient concentrations.
In conclusion, the benthic diatoms assessment methods are not suitable to detect the effects of hydromorphological pressures.

Benthic invertebrates methods
Table 34 gives an overview of key characteristics of 29 assessment methods using benthic invertebrates applied in 28 European countries. All methods except three are based on multi-habitat sampling that is undertaken on 1-5 single sampling occasions. Three methods use a habitat-specific sampling protocol. The number of replicates used to classify a site varies from 1 (for 31% of the methods) to >5 (for 45% of the methods). All methods are multimetric assessment systems, including metrics based on species composition. Diversity is included in 45% of the benthic invertebrate methods.
Most benthic invertebrate methods respond to multiple pressures. Exceptions are three methods that are specifically designed to detect the effects of acidification. Organic/nutrient pressures are picked up by 66% of the methods. Hydromorphological pressures are covered; for 59% of the methods it is explicitly reported that they respond to hydromorphological pressures. Habitat alteration is explicitly mentioned for 34% of the methods, flow modification for 21% of the methods.
In conclusion, the benthic invertebrate assessment methods seem to be suitable to detect the effects of hydromorphological pressure, but they are not very specific.

Table 31 Features of WFD ecological status river assessment methods (Fish fauna)

Biological Quality Element Fish Fauna																					
METHOD CODE		FIA-AT	IBIP-BE	IBI-BE	CZI-CZ	FBA-EE	FIFI-FI	IPR-FR	FIBS-DE	EQRF-HU	IESF-IT	LZI-LT	NLFISR-NL	F_IBIP-PT	EFI-RO	FIS-SK	SIFAIR-SI	IBICAT-ES	IBI-ES	VIX-SE	FCS2-UK
1. METHOD CHARACTERISTICS																					
A – Sampled Habitat	Multi-Habitat	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Single Habitat					✓															
	No Information																				
B – Number of sampling/survey to classify site	1	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	2-5								✓												
	>5																				
	No Information																✓				
C – Number of spatial replicates to classify site	1				✓	✓	✓	✓	✓	✓		✓		✓	✓	✓			✓		✓
	2-5	✓	✓	✓	✓		✓				✓		✓		✓					✓	
	>5																	✓		✓	
	No Information																✓				
D – Metrics	Abundance					✓	✓	✓	✓	✓					✓					✓	✓
	Biomass	✓		✓																	
	Composition	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Diversity	✓	✓	✓		✓	✓	✓	✓	✓		✓			✓						
	Age Structure	✓				✓	✓		✓												
	No information																✓				
2. SENSITIVITY TO PRESSURES																					
Multi-pressure/General		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Organic/Nutrients				✓		✓	✓	✓	✓				✓	✓	✓					✓	
Acidification		✓							✓				✓	✓		✓				✓	
Chemical Pollution				✓	✓				✓									✓			
Alien Species		✓		✓					✓		✓		✓	✓		✓		✓			
Hydromorphology		✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	✓	
Habitat Alteration		✓		✓	✓	✓	✓	✓	✓					✓	✓			✓	✓		
Flow Modification		✓		✓		✓			✓					✓		✓		✓	✓		
River Continuity					✓																
No Information																	✓				

Table 32 Features of WFD ecological status river assessment methods (Macrophytes)

Biological Quality Element Macrophytes																						
METHOD CODE		AIM-AT	MAFWAT-BE	IBMR-BE	MRI-BU	CMA-HR	IBMR-CY	DSPI-DK	CSQ-EE	IBMR-FR	DEMP-DE	IBMR-GR	MRI-HU	IBMR-IT	MTR-IE	NLMP-NL	MIR-PL	IBMR-PT	BMI-SK	RMI-SI	IBMR-ES	LEAFPACS-UK
1. METHOD CHARACTERISTICS																						
A – Sampled Habitat	Multi-Habitat	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓		✓	✓	✓		✓	✓	✓
	Single Habitat								✓										✓			
	No Information							✓			✓				✓							
B – Number of sampling/ survey to classify site	1	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
	2-5		✓											✓			✓					
	>5																					
	No Information							✓							✓							
C – Number of spatial replicates to classify site	1			✓		✓	✓			✓	✓		✓	✓			✓	✓	✓	✓	✓	✓
	2-5		✓			✓			✓			✓	✓						✓			✓
	>5								✓			✓	✓			✓						
	No Information				✓			✓							✓							
D – Metrics	Abundance			✓	✓	✓	✓			✓				✓		✓		✓		✓	✓	
	Biomass																					
	Composition	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓		✓	✓	✓	✓	✓
	Diversity								✓			✓							✓			✓
	Growth Forms		✓													✓						
	No Information							✓							✓		✓					
2. SENSITIVITY TO PRESSURES																						
Multi-pressure/General		✓	✓	✓			✓			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Organic/Nutrients		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Acidification			✓								✓								✓			
Chemical Pollution			✓																			
Alien Species		✓	✓																			
Hydromorphology		✓	✓	✓		✓	✓			✓	✓	✓	✓	✓		✓		✓	✓		✓	✓
Habitat Alteration		✓	✓	✓			✓			✓	✓	✓	✓	✓		✓		✓	✓		✓	
Flow Modification		✓	✓			✓										✓			✓			
River Continuity																						
No Information					✓			✓							✓							

Table 33 Features of WFD ecological status river assessment methods (Phytobenthos)

Biological Quality Element Phytobenthos																						
METHOD CODE		PB-AT	PISIAD-BE	IPS	PB-BG	CDT-HR	PB-CZ	IBD-FR	PB-DE	PB-HU	ICM-IT	TDI-IE	PB-NL	PIT-NO	PB-PL	PB-RO	PB-SK	PB-SI	MDIAT-ES	PB-SE	DARLEQ-UK	DARES-UK
1. METHOD CHARACTERISTICS																						
A – Sampled Habitat	Multi-Habitat	✓									✓		✓		✓	✓		✓				✓
	Single Habitat		✓	✓	✓	✓	✓	✓	✓	✓							✓			✓		
	No Information											✓		✓					✓		✓	
B – Number of sampling/ survey to classify site	1	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓			✓		✓		
	2-5			✓			✓						✓			✓	✓					
	>5																					✓
	No Information											✓		✓					✓		✓	
C – Number of spatial replicates to classify site	1		✓	✓		✓		✓	✓				✓									
	2-5		✓	✓		✓	✓			✓			✓		✓			✓		✓		
	>5														✓	✓				✓		✓
	No Information	✓			✓						✓	✓		✓			✓				✓	
D – Metrics	Abundance				✓											✓						
	Biomass																					
	Composition	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓
	Diversity	✓														✓						
	No Information					✓								✓					✓		✓	
2. SENSITIVITY TO PRESSURES																						
Multi-pressure/General		✓	✓	✓		✓		✓	✓	✓	✓		✓		✓	✓	✓			✓		✓
Organic/Nutrients		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓
Acidification			✓						✓				✓							✓		
Chemical Pollution			✓	✓						✓												
Alien Species																						
Hydromorphology			✓		✓	✓			✓							✓						
Habitat Alteration						✓			✓							✓						
Flow Modification			✓			✓																
River Continuity																						
No Information														✓					✓		✓	

Table 34 Features of WFD ecological status river assessment methods (Benthic Invertebrates)

Biological Quality Element Benthic Invertebrates																														
METHOD CODE		BI-AT	MMIF-FL	IBGN	BI-BG	ICMi-cy	BI-HR	BI-CZ	DSFI	BI-EE	MMI-FI	PERLODES-DE	BI-HU	MO-IT	Q-IE	BI-NL	AI-NO	BMWP-PL	RIVECO-PL	BI-PT	BI-RO	BI-SK	BI-SI	IBMWP-ES	METI-ES	MISA-SE	DJ-SE	ASPT	AWICsp-UK	RICT-UK
1. METHOD CHARACTERISTICS																														
A – Sampled Habitat	Multi-Habitat	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓	✓				✓	✓
	Single Habitat																									✓	✓	✓		
	No Information																✓	✓			✓									
B – Number of sampling/ survey to classify site	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓				✓			✓		✓	✓	✓	✓	✓	✓
	2-5					✓		✓								✓					✓	✓		✓						
	>5													✓																
	No Information														✓		✓	✓												
C – Number of spatial replicates to classify site	1	✓	✓					✓	✓	✓						✓													✓	✓
	2-5																									✓	✓	✓	✓	
	>5			✓		✓	✓				✓	✓	✓	✓						✓	✓	✓	✓	✓	✓					
	No Information				✓										✓		✓	✓												
D – Metrics	Abundance																				✓									
	Biomass																													
	Composition	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Diversity	✓	✓	✓	✓	✓		✓	✓	✓				✓		✓		✓			✓	✓								
	No Information																✓		✓											
2. SENSITIVITY TO PRESSURES																														
Multi-pressure/General		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓			✓		✓
Organic/Nutrients		✓	✓	✓			✓	✓	✓	✓		✓	✓	✓		✓				✓	✓	✓	✓	✓	✓		✓			✓
Acidification		✓										✓								✓						✓			✓	✓
Chemical Pollution			✓																											
Alien Species			✓							✓																				
Hydromorphological		✓	✓			✓	✓	✓	✓	✓		✓	✓	✓		✓				✓	✓	✓	✓		✓					✓
Habitat Alteration		✓	✓			✓				✓			✓	✓						✓	✓	✓			✓					
Flow Modification		✓				✓				✓			✓	✓						✓										
River Continuity																														
No Information					✓												✓		✓											

3.2.2 Biological assessment methods and hydromorphogical pressures

The methods overview in this chapter shows that in principle effects of hydromorphological pressures should be picked up by the biological assessment methods that are in use for classifying rivers for the Water Framework Directive. Biological elements most sensitive to hydromorphological pressures are fish, macrophytes, and benthic invertebrates. However, an important caveat is that methods in use are rather unspecific. They respond to a wide range of pressures including hydromorphological pressures. This is in agreement with the requirements of the Water Framework Directive, where ecological status is defined as the degree of departure from type-specific reference conditions. In other words, ecological status in itself is not defined in terms of pressures. A consequence of the lack of specificity of the biological methods is that there is no guarantee that effects of specific pressures acting at a specific site are picked up by the assessment methods in use, even if methods are sensitive for hydromorphological pressures in general. The biological assessment methods that are currently used will detect that there is a problem with the ecosystem health of a specific water body, but do not give sufficient clues about the causes of the problem. This problem could possibly be solved by further development of biological methods that are specifically designed to detect the effects of certain pressures – but this is unlikely to happen because the Water Framework Directive does not require such methods. A more pragmatic solution is that water managers do not rely on biological assessment methods alone, but directly monitor hydromorphological parameters that will provide more direct clues on which measures are needed to improve the ecological status.

4. Identification of strengths, limitations and gaps of existing methods and recommendations for future progress

In Section 4 we summarize strengths, limitations and gaps of existing methods analyzed in the previous sections. Strengths, limitations and gaps of each of the five identified categories of methods, according to Section 2, are identified and discussed. We finally provide some indications for future progress.

Based on the comprehensive review of hydromorphological methods presented in this report (Section 2), the aim of this section is to identify strengths and limitations of existing methods, comparing them to current hydromorphological theories at varying spatial and temporal scales, and identifying relevant, dynamic parameters, processes, and data gaps.
This analysis is carried out for each of the five categories of hydromorphological methods previously identified, followed by some general considerations concerning the methods implemented by EU countries for the aims of the WFD are outlined. Finally, a summary of limitations and gaps of existing ecological methods and current metrics is provided.

4.1 Physical habitat assessment

Methods of physical habitat assessment aim to characterize the range of physical habitats, heterogeneity and structure of ecosystems. These methods have often a great ecological relevance. The main limitation is that these methods are not suitable to understand physical processes and causes of river alterations, because of a series of reasons, including the scale of investigation (too small), the survey resolution (too much accurate), the temporal scale (not taken into account), the variability of river systems (not covered).

The following main strengths of methods of physical habitat assessment can be remarked:

- They generally provide a framework within which habitat units can be efficiently inventoried and sampled, so that they are useful to characterize the range of physical habitats, heterogeneity and structure of ecosystems.
- These methods often include some specific features of ecological relevance, which are not collected in other categories (such as presence of refuge areas, organic matter, shading, etc.). For these reasons, they are generally helpful to identify the links with communities and ecological conditions.
- While some of these methods are useful for a detailed characterization of physical habitats (e.g. RHS, LAWA, etc.), other methods adopting a more rapid survey protocol can be helpful for an assessment of the overall habitat conditions (e.g. MHR, DHQI).

- Because some of these methods have been largely used across Europe (e.g. RHS and corresponding procedures developed in other countries), they facilitate comparison of data and results from different regions.

Physical habitat assessment has long been considered to be equivalent to hydromorphological assessment, but it is now recognised that it represents only one component of a hydromorphological evaluation. Indeed, when physical habitat methods are used with the aim of understanding physical processes and causes of river alterations, they are affected by a series of limitations (Fryirs et al., 2008, Entwistle et al., 2011), of which the following can be noted:

- The spatial scale of investigation: in most cases this is the same scale as the 'site' and is typically a fixed length of the order of a few hundred meters. This length is usually inadequate for the accurate diagnosis and interpretation of any morphological alteration, since physical site conditions commonly stem from processes and causes that occur at a wider scale.
- Physical habitat assessment methods generally require very detailed site-specific data collection, and their application to large numbers of water bodies may be impracticable.
- Generally, limited use is made of geomorphological methods other than field surveys. For example, remotely sensed data sets, and GIS analysis, which would permit wider spatial and temporal scales of analysis, are rarely used.
- Observations are usually viewed in a static way, rather than placing them in the temporal context within which channel processes operate and river channels adjust. This is probably the main limitation of physical habitat assessment methods, because it prevents the development of a sound understanding of the response of hydromorphology to pressures (i.e. cause-effect) which is essential for implementing appropriate rehabilitation actions (Kondolf et al., 2003a; Fryirs et al., 2008).
- The use of reference conditions based on statistical analyses of empirical data obtained from reference sites can also be a limitation. Selection of reference sites can be problematic, given that many different morphological typologies should be represented. The use of 'natural' sites is also questionable, because sites without artificial elements could still be morphologically altered by disturbances occurring in other portions of the river network (upstream or downstream) and/or that may have occurred in the past.
- Related to the previous point, inherent to many physical habitat assessment methods is the tendency to define high status/reference conditions on the basis of the presence and abundance of features. As a result, many of these procedures implicitly identify high status conditions with maximum morphological diversity for all types of rivers, failing to recognize that in many cases the 'natural' geomorphic structure of a particular stream type may be very simple whereas in other cases it may be more complex (Fryirs, 2003).

Furthermore, the following limitations have been identified when physical habitat methods are used with the aim of characterizing channel forms and morphological units:

- There is usually a notable difference between the terminology used to describe morphological units in habitat surveys, and the present state of the art in Fluvial Geomorphology. For example, most of the methods refer only to riffles and pools when describing bed configuration. This is probably related to the fact that most habitat survey methods have been developed to represent single-thread, gravel-bed rivers. As a result, there is a limited consideration on the wide variety of bed morphologies found in steep, mountain, cobble- or boulder-bed streams, where many additional morphological units are possible (cascades, rapids, glides, step-pools, etc.) in addition to riffles and pools. Considerable progress has been made in the description and terminology associated with morphological units found in mountain streams (e.g. Halwas & Church, 2002; Comiti & Mao, 2012) that post-date the development of most physical habitat assessment methods. There is, therefore, a need to update and integrate these units and relevant terminology into physical habitat survey methods.
- Similarly, morphological units found in rivers with complex, transitional or multi-thread patterns (i.e. braided or wandering) are not adequately covered, although some effort has been recently made to represent some of these morphologies (including ephemeral or temporary streams typical of some Mediterranean regions in South Europe). In the case of large rivers with complex morphologies (e.g. many piedmont Alpine rivers), field survey alone is inadequate to characterize channel forms and morphological units, and so the incorporation of remote sensing techniques is essential.

4.2 Riparian habitat assessment

Methods of riparian habitat assessment adopt a similar approach to river habitat assessment, but focusing on the riparian component. They generally suffer the same limitations as for the previous category (limited spatial and temporal scale, poor understanding of physical processes, etc.) but they successfully integrate vegetation in the assessment of river status. These methods have been developed mainly in southern European countries; they need validation and/or adaptation to be applied in other countries.

Methods devised for assessing riparian habitats usually adopt a similar approach to river habitat assessments. As a result, many of the shortcomings of physical habitat assessments also apply to riparian habitat assessments. However, the following specific strengths can be outlined:
- These methods are well integrated with the previous category, given that physical habitat assessment is normally more focussed on the river channel. Therefore, they are extremely important in accomplishing a requirement of the WFD, i.e. the consideration of vegetation as a key biological element, which otherwise is often neglected.
- While most of these methods are based on field survey and are very focussed on the 'site' scale, some of them (e.g. RQI) can be well integrated with other

hydromorphological components in terms of approaches (e.g. integrated use of remote sensing and field survey) and spatial scale ('reach').

Furthermore, the following specific limitations can be pointed out:

- Many riparian habitat assessment methods are essentially an inventory of habitats and vegetation conditions observed along a portion of river. As a result, there is limited consideration of the processes generating riparian conditions and causes of alteration at larger spatial and temporal scales.
- As with river habitat surveys, the spatial scale of investigation is often small, typically focussing on a fixed length, river margin 'site' of the order of a few hundred meters. The main approach is a field survey along the site, while the use of remote sensing and GIS analysis applied to a wider spatial scale remains, with a few exceptions, limited.
- Riparian habitat assessments are not widely used in Europe. Most methods have been developed in southern countries (e.g. Spain, Italy), where flashy flow regimes and ephemeral, multi-channel patterns (incorporating vegetated islands) are more frequent. Consequently, the recorded types of vegetation are often representative of southern countries. Their validity when applied more widely to other European climatic, hydrological and morphological conditions needs to be verified.

4.3 Morphological assessment

Morphological assessment methods take into account physical processes at appropriate spatial and temporal scales. The main limitation is linked to the complexity in assessing and understanding physical processes; indeed these methods need to be applied by specialists and the assessment is often limited by data availability (e.g. historical photo and maps, GIS data etc.).

The main strength of this category can be summarized as follows:

- Compared to the previous categories, these methods make use of a more robust geomorphologically-based approach by an integration of remote sensing and field survey, with a stronger consideration of physical processes at appropriate spatial and temporal scales. Such an approach supports the development of a better understanding of cause-effect relationships.
- In most cases the basic spatial unit for the application of the assessment procedure coincides with the 'reach' (i.e., a section of river along which present boundary conditions are sufficiently uniform, commonly a few kilometres in length), that is a geomorphologically meaningful spatial scale.
- In some cases (e.g., MQI), the temporal component is explicitly accounted for by considering that an historical analysis of channel adjustments provides insight into the causes and time of alterations and into future geomorphic changes.

However, some of the previous strengths can, to some extent, also imply a series of limitations, including the following:

- Physical processes are generally difficult to assess. Assessing the correct functioning of processes is certainly more difficult than a simple inventory of existing forms. A rigorous evaluation of processes requires the collection of measurements at different times and process rates (e.g. bank erosion or deposition) and/or quantitative modelling or analyses of changes in the process regime (e.g. alterations in sediment transport or channel-forming discharge), which are not feasible within the context of a practical hydromorphological assessment that can be applied by public agencies and managers. For these practical reasons, recorded indicators of processes are usually generated from a static visual assessment (in the field or based on remotely-sensed information) of the occurrence or absence of active processes. In other cases, the evaluation is based on the presence of artificial elements, which are inferred to have significant effects on some processes. For example, the simple presence of transversal structures is often assumed to alter sediment fluxes and continuity, without any quantitative evaluation of the magnitude of the effects of these structures.
- Some of the frameworks that have been included in this review, as for example the River Styles Framework (Brierley and Fryirs, 2005), are based on a sound geomorphological approach and have been demonstrated to be very effective for applications to river management and restoration. However, their practical application by public agencies within the context of the WFD implementation can be problematic, as they need to be applied by specialists.
- Another potential strength of some morphological assessment methods is that the temporal component is sometimes explicitly accounted for by considering channel adjustments (i.e. changes of channel form through time). However, the analysis of channel adjustments is often critical, given that it is difficult and requires specialist expertise, specific data, GIS analyses (e.g. to analyze channel planimetric changes). Furthermore, the definition of the temporal interval of analysis can be questionable. In some cases, a comparison with historical channel conditions may implicitly incorporate the assumption that the past state is a reference condition.
- Definition of a reference state for morphological conditions is problematic. As previously remarked (see section 2.1), there is still a debate on this topic and a common vision of reference conditions is lacking, implying that different methods may make use of different definitions of reference conditions (however, this is also true for the previous categories of methods).
- The focus of these methods is generally on fluvial forms and processes at wider spatial and temporal scales compared to the physical habitat assessment. On the other hand, there is often limited attention given to a systematic inventory of the morphological units and their assemblages that characterize a given morphology, while this is the main focus of physical habitat assessment and is useful for ecosystem characterization. This lack of morphological inventory can be a limitation when morphological assessment is used alone.

- Generally, these methods evaluate morphological conditions exclusively in terms of physical forms and/or processes, without any inferences made concerning their consequences or implications in terms of ecological state. This means that a high morphological quality is not necessarily related to a good ecological state, although this is commonly the case. In fact, it is widely recognized that functioning of physical processes and 'dynamic equilibrium' spontaneously promote ecosystem diversity and functioning. However a clear relation between some of the morphological indicators used in these methods and biological responses is currently lacking (this is in fact one of the objectives of the project REFORM as a whole).

4.4 Assessment of hydrological regime alteration

Methods for the assessment of hydrological regime alteration make use of indicators derived by quantitative, statistical or physically-based models. This implies the use of existing large data sets and long-time series, which represent the main limitation. Moreover these methods often do not take into account small scale hydrological alterations (e.g. hydropeaking) as well as groundwater/surface interactions, important for organisms.

The main strength of this category can be identified with the following:

- These methods make use of robust indicators based on quantitative, statistical or physically-based models. Most European methods are based on some or all of the Indicators of Hydrologic Alteration (IHA) proposed by Richter et al. (1996) and Poff et al. (2003).

Conversely, the following limitations can be remarked:

- The previous strength can often be seen as a limitation, because the use of such indicators and models generally requires large data sets and long-time series, which are often not available. In particular, the application of such methods to ungauged streams is problematic. If models are applied when data are not available or to infill incomplete data series, the problem of uncertainties that can affect the estimation should be carefully considered.
- Related to the previous point, a critical issue is the definition of the unaltered ('natural') reference hydrological regime. This requires a sufficiently long data series describing pre-impact conditions, which in most cases is not available. The identification of pre-impact conditions data series that represent 'natural' conditions can be also questioned, particularly in Europe where river systems have been affected by alterations at a catchment scale, that strongly influence the hydrological regime, since historical times.
- The analysis of existing hydrological pressures rather than using quantitative data (e.g. some non-European method based on the presence and type of impacts and causes of alteration) can be more feasible from a practical point of view. However, it can be extremely difficult to correctly evaluate the effects of a given pressure in the absence of a quantitative analysis of hydrological data.

- Indicators of hydrological alteration are based, at best, on daily discharges. This prevents the analysis of hydrological alterations that occur at shorter time scales, such as hydropeaking (as well as thermopeaking), that have very important effects on ecological communities. Specific indicators and/or models for analyzing hydropeaking are needed. Recent progress has been made in the development of integrating approaches to assess hydrological alterations due to hydropower impacts (e.g. Zolezzi et al., 2009) and these should be taken into account for future developments of hydrological assessment methods.
- The effects of groundwater alterations are generally not included in these methods apart from an indirect assessment through low-flow analyses. Groundwater systems are an important component of riverine ecosystems and so methods are needed to take them into account.
- Because of the above limitations, the practical use of these methods for supporting the hydromorphological assessment required to deliver the requirements of the WFD by public agencies is still limited.

4.5 *Longitudinal continuity assessment*

Methods for longitudinal continuity assessment mainly consists of an inventory of features or on an assessment of barrier passability at the single barrier scale, rather than on the effective assessment of river longitudinal continuity at the catchment scale. Despite recent progress, efforts are still needed to combine small scale assessment and large scale inventories, species biology, spatial/regional environmental diversity and river processes.

The following strengths of this category can be highlighted:

- Inventories of existing barriers at catchment scale are useful not only for fish continuity, but also for other types of assessments, such as longitudinal continuity of sediment transport and flows.
- Many of these methods have been developed and can be useful to prioritize river management and restoration (e.g. barrier removal, etc.).
- Combining large scale inventory with local scale assessment (e.g. ROE and ICE protocols in France) could represent a valid alternative to simple local scale assessment methods, but up-scaling local assessment to catchment scale needs further developments (e.g. cumulative effect of barriers for a large range of fish communities and environmental conditions).
- Recently, to avoid the problem of combining biological and physical assessment of barriers at the catchment scale, modelling techniques have been developed. They are powerful, but need further development to capture the variability in fish biology/ecology and river processes (Bourne et al., 2011).

Conversely, the following main limitations of this category can be identified:

- As previously described (see section 2.5), many of these methods are aimed at building an inventory of existing barriers, while relatively few methods carry out any deeper assessment.

- Assessing fish longitudinal continuity is complex, as it should account for variability in fish biology, structures, hydrological regimes, as well as for the temporal variability of all these factors.
- Few standardized protocols/structured methods exist.
- Many methods focus only on species of economic importance (i.e. in North America), and so they do not take account of differences in the requirements of different species or their life-stages including differences in migratory behaviour.
- Existing methods often are applicable at one of two very different spatial scales (i.e. large database inventories at large scales vs. assessments of passability at the scale of individual structures).
- At the local scale, the assessment of the characteristics of physical structures and their passability from the perspective of different fish species is relatively recent (since the beginning of 2000s). Furthermore, biological sampling techniques exist that can assess barrier passability (e.g. tracking, telemetry, direct observations/filming; Kemp & O'Hanley, 2010; Bourne et al., 2011). Both types of assessment (i.e. barrier assessments and the measurements of fish passage) are spatially limited and not integrated in a catchment context.

4.6 Methods implemented by EU countries for the WFD

The main gap in methods implemented by EU countries for the WFD is the lack of consideration of physical processes (i.e. cause-effect of alterations), when physical habitat assessment is used alone. The 5 identified categories of methods need to be considered as part of an overall hydromorphological assessment.

The methods formally adopted or commonly used by EU countries to comply with the WFD are included in some of the categories of methods previously analyzed, and so their specific limitations are summarised in the previous discussion. Some additional limitations of hydromorphological assessment methods employed within the EU can be made as follows:

- Consideration of physical processes by EU countries in the assessment of hydromorphological conditions remains the main gap (with the exception of those countries where a morphological assessment method is used). This is an important limitation because a characterization of physical habitats alone is not sufficient to develop understanding of the causes of alterations and responses to them (i.e. cause-effect), which are extremely important for the implementation of rehabilitation actions (Kondolf et al., 2003a; Fryirs et al., 2008).
- As a consequence of the wider availability of methods for physical habitat assessment and their relative simplicity, in most cases this type of approach has been identified as an appropriate procedure for the stream hydromorphological assessment required by the WFD. Limitations of this category of method have been previously discussed, but it is important to re-emphasize that physical habitat assessment is only one component of an

overall hydromorphological assessment. At present, few EU countries are assessing and integrating the different components of hydromorphology. Notable exceptions are France and Italy.
- For future hydromorphological assessment and monitoring, an integrated use of more components is required to achieve an overall assessment, and a particular emphasis on morphological and hydrological methods is strongly recommended.

4.7 Ecological methods and current metrics

Methods for the assessment of the river ecological status have been established for the large majority of European countries for all the biological quality elements of the Water Framework Directive. Ecological methods are able to detect the effects of hydromorphological pressures on biota but are not able to tell us what the cause of the problem is.

The following limitations can be identified based on the review of the methods in use:
- River ecological status assessment methods have been established for the large majority of European countries for the biological quality elements Fish fauna, Benthic Invertebrates, Benthic Diatoms and Macrophytes.
- Status assessments for the Water Framework Directive are required to be carried out at the level of the water body, for rivers this is in most cases equivalent with the reach.
- The Water Framework Directive defines ecological status as departure from reference conditions; by definition, ecological status is therefore a concept that is not dependent on specific pressures (Caroni et al., in press).
- As a consequence, ecological methods that are currently in use are not very pressure-specific, with the exception of methods using Benthic Diatoms methods that tend to be specific for the effects of nutrients and eutrophication. The methods for the remaining biological quality elements do cover effects of hydromorphological pressures, but they do also respond to other pressures.
- Very little information is available on the response of individual assessment methods to specific hydromorphological pressures.
- In conclusion, the methods in use will in principle detect the effects of problems caused by hydromorphological pressures when they occur, but the status assessment by itself will not tell us what the cause of the problem is. Further information characterising the pressures (physicochemical and hydromorphological) is required to be able to identify the problems and to plan appropriate measures.

4.8 Recommendation for future progress: development of a process-based eco-hydromorphological framework

The main recommendations for future progress for eco-hydromorphological assessment are the following: 1. To improve the understanding of the relationship between organisms and hydromorphological pressures; 2. The need of process-based assessment methods; 3. The identification of appropriate spatial and temporal scales for the application of the assessment methods and for linking processes by a hierarchical spatial framework; 4. The identification of the most suitable methods, by including all the components of hydromorphological conditions (morphology, hydrology, physical and riparian habitats, longitudinal continuity for fish), by testing and adapting them to other European contexts; 5. The need for improving physical habitat assessment by including a geomorphologically-based survey in terms of techniques and improved terminology; 6. To provide a practical and simple initial screening tool to identify critical hydromorphological conditions at catchment scale.

Based on the limitations and gaps identified in the previous sections in relation to existing methods for eco-hydromorphological assessment, the following main recommendations for future progresses are outlined.

1. Concerning the ecological methods, further studies are needed to understand which groups of organisms and ecological indicators are able to detect the effects of hydromorphological pressures.
2. Consideration of physical processes should be enhanced in hydromorphological assessment methods. This can be achieved by a wider use and implementation of methods for morphological assessment, and by increasing their capability for assessing geomorphic processes. Most of existing methods implemented to comply with the WFD by EU countries are exclusively based on a physical habitat assessment. It must be recognized that physical habitat assessment is only a component of an overall hydromorphological assessment.
3. Assessment of morphological processes and alterations should be included in an appropriate spatial hierarchical framework and scaling methodology, emphasizing relevant spatial units and temporal time scales, and identifying key controlling factors at each spatial scale as well as appropriate morphological indicators.
4. Because of the range of existing methods, development of a completely new methodology is unnecessary. Rather, the effort should be in combining, selecting, improving and testing existing approaches to achieve an integrated framework that takes into account recent developments and principles in assessing river condition (e.g. Fryirs et al., 2008). This will involve testing the selected methods across a wider, European context, and where gaps emerge, the methods may require modification to best suit the conditions under which they are being applied.
5. The development of a framework for integrated hydromorphological analysis is recommended, where the morphological and hydrological components are

key parts of the evaluation and classification of hydromorphological state and quality. Physical habitat and longitudinal fish continuity should represent an additional characterisation of the overall stream conditions at representative sites.

6. A particular focus needs to be placed on the physical habitat assessment component. As noted previously (see section 4.1), a gap exists in the terminology used to describe morphological units. The development of a new protocol for the inventory of morphological units would be extremely useful for future applications of physical habitat assessment methods, without excluding integration with existing methods. This protocol should cover a wider range of channel morphologies (e.g. steep mountain streams, wandering or braided alluvial rivers), taking into account recent progress in this field of fluvial geomorphology, and including a stronger integration between remote sensing techniques (particularly for large, alluvial rivers) and field survey.
7. Most of the hydromorphological assessment methods require time demanding data collection and analysis, and their application to a wide number of reaches by agencies in charge of the WFD monitoring is unfeasible. Together to the need for a more comprehensive hydromorphological assessment, there is also the necessity for developing a simpler tool which can be used for an initial screening and identification of critical hydromorphological conditions at catchment scale.

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6. Appendices

Appendix A: Definitions of the table entries for the groups of methods from 1 to 3 (Physical habitat assessment, Riparian habitats assessment, Morphological assessment)

Appendix B: Definitions of the table entries for the group of methods 4 (Hydrological regime alteration)

Appendix C: Definitions of the table entries for the group of methods 5 (Longitudinal continuity for fish communities)

Appendix D: Definitions of the table entries for the European methods implemented for the WFD

Appendix E: Description of the methods implemented by European countries for the WFD: 1. Method background; 2. Method characteristics; 3. Recorded features; 4. River processes; 5. Application to WFD

Appendix E 1 – Guidelines for assessing the hydromorphological status of running waters (Austria)
Appendix E 2 – HEM (Czech Republic)
Appendix E 3 – DHQI (Denmark)
Appendix E 4 – RHS (England and Wales)
Appendix E 5 – CarHyCE (France)
Appendix E 6 – SYRAH-CE & AURAH-CE (France)
Appendix E 7 – ROE & ICE (France)
Appendix E 8 – LAWA-FS (Germany)
Appendix E 9 –LAWA-OS (Germany)
Appendix E 10 – RHAT (Northern Ireland & Republic of Ireland)
Appendix E 11 – CARAVAGGIO (Italy)
Appendix E 12 – MQI (Italy)
Appendix E 13 – Methodology for the assessment of hydromorphological changes (Latvia)
Appendix E 14 – Handboek HYMO (The Netherlands)
Appendix E 15 – MHR (Poland)
Appendix E 16 – RHS adaptation (Portugal)
Appendix E 17 – MImAS (Scotland)
Appendix E 18 – HAP-SR (Slovakia)
Appendix E 19 – SIHM (Slovenia)
Appendix E 20 – IHF (Spain)
Appendix E 21 – QBR (Spain)

Appendix A: Definitions of the table entries for the groups of methods from 1 to 3 (Physical habitat assessment, Riparian habitats assessment, Morphological assessment)

1. METHOD CHARACTERISTICS			**In this section some general information and basic characteristics of each method are provided (e.g. general survey strategy, spatial and temporal scales, etc.)**	**Group of methods**
A - SOURCE OF INFORMATION / DATA COLLECTION		Map and/or remote sensing Field survey Rapid field assessment Modelling	It refers to the source of information and to the approach used for data collection. "Field survey" and "Rapid field assessment": indicate a more detailed field survey or a rapid assessment respectively	1 to 3 1 to 3 1 to 3
B - SPATIAL SCALE	LONG. SPATIAL SCALE	Fixed length Length scaled to channel width Variable length	It reports the longitudinal spatial scale of application of the method	1 to 3 1 to 3 1 to 3
	LAT. SPATIAL SCALE	Channel Banks/Riparian zones Floodplain	It describes the lateral areas of the river corridor investigated	1 to 3 1 to 3 1 to 3
C - TEMPORAL SCALE		Present Recent Historical	It identifies the temporal interval covered/assessed by the method Present = during the survey; Recent = last 1-10 years; Historical = more than 10 years (generally last 10 - 50 years)	1 to 3 1 to 3 1 to 3
D - TYPE OF METHOD		Characterization/classification	The method aims to characterize and/or make a detailed inventory of the features	1 to 3
		Assessment by index	The method aims to assess the hydromorphological conditions by the use of one or more indexes; it classifies a final status by the definition of quality classes	1 to 3
		General assessment/Design framework	The method makes a general assessment of the river conditions by a broader perspective and/or could be a framework for the design of river restoration projects	1, 3
E - REFERENCE CONDITIONS			Does the method refer to any reference condition? (Estimating deviation from reference values, potential use of metrics to define reference conditions, etc.)	1 to 3
2. RECORDED FEATURES			**In this section some basic information on the recorded features of each method at the different spatial scale is provided**	
A - CATCHMENT / VALLEY		Large scale characteristics	Are large scale characteristics recorded? It indicates whether the method is only focused on local scale (site) or some information at catchment scale is provided	1 to 3
		Hydrological regime/Discharge	It refers to some general information on hydrological conditions at catchment scale (not necessarily referred to the reach of application)	1 to 3
		Valley form/features	It indicates whether valley form and features are considered	1 to 3
B - CHANNEL		Channel pattern/planform	Are the channel pattern and/or planform recorded? Pattern refers to the channel configuration (e.g. straight, meandering, braided, etc.); planform refers to other planimetric characteristics and /or parameters (e.g. channel sinuosity, braiding index, etc.)	1 to 3
		Channel forms and/or bed configuration	Are channel forms (e.g. bars, islands, etc.) and bed configuration (e.g. riffle-pool, etc.) recorded?	1 to 3
		Channel dimensions	Are channel dimensions provided?	1 to 3
		Flow-type	Are flow types recorded?	1, 3
		Substrate	It refers to any type of information concerning substrate characteristics (e.g. sediment type, size, etc.) including substrate alterations (e.g. armouring, clogging, bedrock outcropping, etc.)	1 to 3

	Physical parameters	Does the method measure physical parameters (e.g. flow velocity, flow depth, etc.)?	3
	In-channel vegetation	It records only in-channel vegetation (e.g. macrophytes, mosses, filamentous algae, etc.)	1 to 3
	Woody debris	Does the method collect any information on woody debris?	1 to 3
	Artificial features and structures	It means any artificial in-channel features (weirs, sills, etc.)	1 to 3
C - RIVER BANKS/ RIPARIAN ZONE	Bank profile/shape	It refers to any information about the physical structure of the banks (e.g. height, slope, shape, etc.)	1 to 3
	Bank material	It records any type of information concerning bank substrate characteristics (e.g. bank type, sediment size, etc.)	1 to 3
	Riparian vegetation structure	Does the method collect any information on riparian vegetation structure?	1 to 3
	Longitudinal continuity of riparian vegetation	Does the method collect any information on riparian vegetation longitudinal continuity?	1 to 3
	Riparian vegetation width	It refers to the width of functional vegetation in the fluvial corridor: does the method require any information on the lateral extent of riparian vegetation?	1 to 3
	Riparian vegetation composition	Does the method give additional information on vegetation specie composition (e.g. dominant species, alien species, etc.)	3
	Autochthonous/Exotic species	Does the method record any specific information on vegetation species and communities?	2
	Species distribution/coverage		2
	Vegetation regeneration	Does the method record any information on the regeneration of riparian vegetation?	2
	Riparian soil	Does the method record any information on the substrate of the riparian area?	2
	Artificial features and structures	It refers to any artificial features located on the banks or in the riparian zones (e.g. bank protections, artificial levees, etc.)	1 to 3
	Land use	It refers to the land use on the banks and in the riparian zone (e.g. roads, houses, farms, cultivated areas, etc.)	1 to 3
D - FLOODPLAIN	Fluvial forms	Are fluvial forms in the floodplain (e.g. oxbow lakes, wetlands, secondary arms, etc.) recorded?	1 to 3
	Floodplain dimensions	Are floodplain dimensions provided (e.g. width)?	3
	Floodplain deposits	Does the method provide information on the composition of floodplain deposits?	3
	Land use	It indicates the land use in the floodplain	1 to 3
3. RIVER PROCESSES		**In this section some information is provided on whether the method explicitly accounts for some physical river processes (e.g. lateral/longitudinal continuity, channel adjustments, etc.). In some cases, this type of information could be indirectly derived from other recorded features (e.g. artificial structures, channel forms, etc.)**	
A - LONGITUDINAL CONTINUITY		It refers to the longitudinal mobility of water, sediment, wood and organisms	1 to 3
B - LATERAL CONTINUITY		It refers either to the lateral hydraulic continuity (connectivity of water flow between the river channel and its riparian zone and/or the floodplain) and sediment and wood continuity (sediment delivery by bank erosion, hillslope river-corridor connectivity, etc.)	1 to 3
D - BANK EROSION / STABILITY		Does the method record the presence and/or the extension of eroding banks and/or provide information on bank stability?	1 to 3
E - CHANNEL ADJUSTMENTS		Does the method consider planimetric (changes in channel pattern, width, etc.) and/or vertical (incision, aggradation) channel adjustments?	1 to 3
F – VERTICAL CONTINUITY		Does the method assess the connection to between river and groundwater?	3

Appendix B: Definitions of the table entries for the group of methods 4 (Hydrological regime alteration)

1. METHOD CHARACTERISTICS		**In this section some general information and characteristics of each method are provided (e.g. survey strategy, spatial and temporal scales, etc.)**
A - SOURCE OF INFORMATION / DATA COLLECTION	Map and / or Remote sensing Existing hydrological data series Monitoring or measurement (field) Modelling (data are estimated / reconstructed)	It refers both to the source of information and to the approach used for data collection/analysis
B - SPATIAL SCALE	River catchment Water body Reach Cross section	
C - TEMPORAL SCALE	Monthly data Daily data Hourly data Other	
D - RIVER TYPOLOGY APPLICATION	Not limited to specific river typologies Limited to specific river typologies	
E - TYPE OF ASSESSMENT	Single index Multiple index Modelling Final expert judgment	It provides information on the modality of assessment of the hydrological alterations (use of index, modelling, expert judgment)
F - REFERENCE CONDITION	Known pre-impact natural condition Reconstructed pre-impact natural condition	Expert judgment / Existing databases / Analogue unmodified site From measured series corrected by impact effect
G - PREDICTIVE ABILITY	Models and scenarios for evaluation of pressure changes Models and scenarios for evaluation of restoration measures No predictive assessment	Does the method predict the risk of deterioration (following changes in pressures) and / or the effects of restoration measures?
H - STRENGTHS / GAPS OF THE METHOD	Easy to apply Applicability for different lengths of data series Procedure for gauged and ungauged stations A priori evaluation of pressures	Applicability not dependant from length of the data series Does the method include distinct procedures for gauged and ungauged sites? Assess pressures (existence and magnitude) before the application
I - CONNECTION TO ECOLOGY	Influence on ecological status	Is the method used as a supporting element in estimating the ecological status?
2. RECORDED FEATURES		**In this section some basic information on the recorded features of each method is provided**
A - HYDROLOGICAL CONDITIONS	Flow regime Discharge Changes in flow depth Flow velocity Shear stress	

	Other	
B - METRICS OF FLOW REGIME	Magnitude Frequency Duration Timing (seasonality) Rate of change (rapidity) Minimum flow Maximum flow Variability (annual) Interannual variability (climate) Intermittent flows	Information on the day of the year during which low or high flow condition are recorded Information on the difference between maximum and minimum during a year and/or day E.g. distinction between dry and wet years
C - ASSESSED PRESSURES (or to what pressure the metrics respond?)	Intakes, transfers and by-passes of water Groundwater interaction (e.g. abstraction) Hydro-peaking Impoundment - change in hydrology Lateral (widening/narrowing) and vertical (deepening) changes adjustments - change in hydrology Large scale pressures (e.g. land use)	It refers to pressures in the floodplain and/or in the upstream portion of catchment

Appendix C: Definitions of the table entries for the group of methods 5 (Longitudinal continuity for fish communities)

1.METHOD CHARACTERISTICS		**In this section some general information and characteristics of each method are provided (e.g. survey strategy, spatial and temporal scales, etc.)**
A - DATA COLLECTION	Map and/or remote sensing Field survey Rapid field assessment Existing database Modelling	
B - SPATIAL SCALE	River network River Single barrier	
C - HABITAT ASSESSEMENT	Defined length (reach between two barriers) Use of metrics to define available habitats (using species requirements, e.g. habitat suitability)	It is linked to the definition of habitat for the method application and to the assessment of habitat loss
D - TYPE OF METHOD	Barrier passability assessment Barrier characterization and Modelling Database inventorying and/or Mapping Use of a final index Habitat loss assessment Fish telemetry (Radio-tracking)	The method gives only a passability value to the barrier The method characterize the features and models the passability of the barrier E.g. the French inventorying of longitudinal discontinuities (ROE & ICE) The method also assesses the habitat loss It is not really a hydromorphological assessment but is still one of the most common method for fish longitudinal continuity assessment in Europe
E – CRITERIA FOR PASSABILITY ASSESSMENT	Fish biology (physiology, swim speed estimation, life history etc., within and / or amongst species) Chemical attributes and temperature Temporal environmental variations (e.g. variation in water level/discharge) Hydrological attributes (e.g. discharge, water level) Physical attributes of the barrier (e.g. dam height, etc.) Effect of multiple barriers Presence of a fish pass Downstream/Upstream passability assessment	It refers to the criteria that are considered in the assessment of the passability value (note: life history is important and barriers strongly impact diadromous species). It does not necessarily refer to measured parameters but to the factors that are taken into account
F - FISH COMMUNITY / SPECIES APPLICATION	Calibration for life history and/or behaviour of specific species (diadromy, potadromy, etc.); environmental value Only for some species of interest	It specifies whether the method is applicable to several fish communities or has been developed only for some group of communities (e.g. those of interest for fisheries)

2.RECORDED FEATURES		**In this section some basic information on the recorded features of each method is provided**
A - LARGE SCALE PASSABILITY ASSESSEMENT	River network configuration	It refers to the pattern of the river network (e.g. dendritic, etc.)
	Number of barriers	Does the method asses the number of barriers?
	Spatial location of barrier	Does the method account for the spatial location of barriers?
	Natural/artificial barrier	
	Segment/river length	It refers to the ration between river segment interested by the barrier and river length
	River flow parameters	Does the method assess river flow parameters for the definition of barrier passability?
B - BARRIER CHARACTERISTICS (BARRIER SCALE)	Flow parameters (velocity, depth, discharge, etc.) Cross-section topography Physical attributes (slope, length, shape, material, etc.) Inflow/Outflow drop height Presence of an outflow pool Type of barrier (dam, weir, culvert, natural, etc.) Presence of a bypass channel	It refers to local features measured in correspondence of the barrier
C - FISH PASS CHARACTERISTICS (if present)	Natural/close to natural facilities	E.g. fish ramps, bed ramps, lateral rivers / canals / channels, etc.
	Technical fish pass (general meaning) / Mechanised / Specific technical fish pass	E.g. staircases, ramps, etc. / gates, lifts, fish pumps, etc. / pass for a specific fish species
	General conditions of the fish pass (water flow, occlusions, danger of predation, etc.)	
	Passability of the fish pass	
D - FISH CHARACTERISTICS	Age Life history Size range Swimming (size/swim speed) and/or jumping abilities Fish species / communities	Characteristics that are used for the assessment of the barrier passability
E – HYDROLOGICAL VARIABILITY	Times series of hydrological parameters	It indicates whether the method accounts for the temporal variability of hydrological parameters and which one (e.g. river stage, discharge, etc.)

Appendix D: Definitions of the table entries for the European methods implemented for the WFD

1 - METHOD BACKGROUND			**In this section the basic information of each method is provided**
NAME OR CODE			
COUNTRY			
KEY REFERENCE			
WEBPAGE			The web address is indicated when available
CATEGORY			It indicates to which of five categories of assessment (physical habitat, riparian habitat, morphological assessment, hydrological regime alteration, fish continuity) the method can be referred
2 - METHOD CHARACTERISTICS			**In this section some general information and basic characteristics of each method are provided (e.g. general survey strategy, spatial and temporal scales, etc.)**
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps and / or Remote sensing Field survey Rapid field assessment Existing database (data series) Modelling	It refers to the source of information and the approach used for data collection. "Field survey" and "Rapid field assessment" indicate a more detailed field survey or a rapid assessment respectively. Short description of map resolution, remote sensing techniques, field survey techniques, rapid field assessment methodologies, and modelling (when used) are provided
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/Reach/Cross Section	It indicates whether a hierarchical nested approach is adopted, and provides a short description of the strategy and/or spatial units
	LONGITUDINAL SPATIAL SCALE	Fixed length Length scaled to channel width Variable length	It specifies the longitudinal spatial scale of application of the method providing a short description
	LATERAL SPATIAL SCALE	Channel Banks/Riparian zones Floodplain	It describes the lateral areas of the river corridor investigated
C - TEMPORAL SCALE		Physical and morphological assessment Hydrological assessment	It identifies the temporal interval covered/assessed by the method. For physical habitat/morphological assessment: Present = during the survey; Recent = last 1-10 years; Historical = more than 10 years (generally last 50 – 100 years). For hydrological assessment: monthly, daily, hourly, other
D - TYPE OF METHOD		Characterization/ classification	The method aims to characterize and / or make an inventory of the features. A short description of the protocol is provided
		Assessment by index	The method aims to assess the hydromorphological conditions by the use of one or more indexes. A short description of the protocol is provided
		Deviation from reference	Does the method assess the hydromorphological state in relation to a reference condition? (The type of reference condition is reported in point E). A short description of the protocol is provided
		General assessment/Design framework	The method makes a general assessment of the river conditions by a broader perspective and/or could be a framework for the design of river restoration projects

	Modelling status/Scenario	Does the method model the final state or some possible scenario of river conditions?
	Final expert judgment	Does the method make use of expert judgment to assess river conditons?
	Links with other systems	Is the method part of a broader evaluation system, or can be used in conjunction with other systems? (Single index / Multiple index / Complex protocol / General framework)
E - REFERENCE CONDITIONS		It refers to the use of reference conditions against which the deviations of the hydromorphological state are assessed. A description of the type of reference conditions (if used) is provided: Theoretical / Empirical / Historical / Modelled / No reference condition. "Theoretical": the method uses a priori reference conditions (e.g. by expert judgment) taken in absence of relevant alterations; "Empirical": the method defines reference conditions based on empirical data obtained from databases and/or practical case studies (a posteriori approach based in reference sites with absence of relevant modifications); “Historical”: reference conditions based on historic information (e.g. old maps or aerial photos); “Modelled”: the method uses modelled condition (including conceptual models); "No reference condition": the method does not make use of reference conditions
F - GENERAL INFORMATION	RIVER TYPOLOGY	It concerns the CEN standard requirements; are rivers subdivided into different classes or types in the system?
	TYPOLOGY LIMITATIONS	It describes whether the method refers to a specific river type of is applicable to any river typology. It aims to identify the gaps of the method application in terms of river typology, i.e. to identify the river typology for which the method is not applicable (e.g. small streams vs. large rivers; confined vs. partly confined vs. unconfined; temporary/ephemeral vs. perennial; wadable vs. not wadable; single-threat vs. multi-thread)
	TYPE-SPECIFIC	It provide information on whether the method uses a type-specific protocol/assessment method/indicators for specific river types or it is applied in the same way to any river typology potentially assessed by the method
	BASIS FOR STANDARDS / THRESHOLDS	It indicates which criteria have been used to set standards/thresholds for status classes: reference sites vs. impacted sites; numeric standards/thresholds for status classes
	REACH SCALE SURVEY STRATEGY	It aims to identify the survey approach at the reach scale, i.e. survey of the whole reach vs. representative site (sub-reach/transect/points)
	TIMING AND FREQUENCY	It provides information on the temporal requirement of the survey
	DATA PRESENTATION (OUTPUT / LAYOUT)	It aims to summarise which kind of outputs are possible: maps, index, classes, etc. (the list is not exhaustive)
	METHOD SUPPORT / APPLICATION TOOLS	It aims to summarise which kind of supports are available: manuals, databases, field sheets forms, compilation forms, etc. (the list is not exhaustive)
	SPATIAL COMPARISON	Does it allow for, or make use of, comparison between different locations? Describe whether comparison is possible/required or not
	CONNECTION TO ECOLOGY	Does the method relate parameters and indicators used to ecology (inventorying features for biota)? Does the method record ecologically-relevant habitat changes (extent, quality, spatial pattern)?indicates whether the connection is direct or not and whether habitat changes are assessed
	USERS	It aims to identify recommended users of the method: scientists, experts, water agencies, local managers, etc. (the list is not exhaustive)

	SCALE INFORMATION		It indicates the spatial scale at which information is provided by the method: small (local), large (catchment), both
	NUMBER OF END PARAMETERS		How many parameters / indicators have to be measured? It is a summary of the total number of measured parameters/indicators
3. RECORDED FEATURES			**In this section some information on the recorded features of each method at different spatial scale is provided. Examples of assessed features, attributes or indicators are reported for each category**
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Are large scale characteristics recorded? It indicates whether the method is only focused on a local scale (site) or some information at catchment scale is provided
	HYDROLOGICAL REGIME / CONDITIONS	Hydrological conditions	It refers to some general information on hydrological conditions at catchment scale (not necessarily referred to the reach of application): flow regime, discharge, depth, velocity, etc.
		Metrics of hydrological (flow) regime	It indicates which metrics the method assesses/records (it applies mostly to methods for the assessing of hydrological regime alteration): magnitude, frequency, duration, timing, rate of change, etc.
		Hydro-peaking	Does the method assess pressures from hydropeaking?
	VALLEY FORM / FEATURES		It indicates whether valley form and features are considered
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Are the channel pattern and/or planform recorded? Pattern refers to the channel configuration (e.g. straight, meandering, braided); planform refers to other planimetric characteristics and/or parameters (e.g. channel sinuosity, braiding index, etc.)
	CHANNEL FORMS		Are channel forms (e.g. bars, islands, etc.) recorded?
	BED CONFIGURATION		Is bed configuration (e.g. riffle / pool) recorded?
	CHANNEL DIMENSIONS		Are channel dimensions provided?
	FLOW-TYPE		Are flow types recorded?
	PHYSICAL / HYDRAULIC VARIABLES		It refers to hydraulic variables such as flow velocity, flow depth, hydraulic geometry, shear stress etc.
	SUBSTRATE		It refers to any type of information concerning substrate characteristics (e.g. sediment type, size, etc.) including substrate alterations (e.g. armouring, clogging, bedrock outcropping, etc.)
	IN-CHANNEL VEGETATION		It records only in-channel vegetation (e.g. macrophytes, mosses, filamentous algae, etc.)
	WOODY DEBRIS		Does the method collect any information on woody debris?
	ARTIFICIAL FEATURES AND STRUCTURES		It means any artificial in-channel features (e.g. weirs, sills, etc.)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		It refers to any information about the physical structure of the banks (e.g. height, slope, shape, etc.)
	BANK MATERIAL		It records any type of information concerning bank substrate characteristics (e.g. bank type, sediment size, etc.)
	RIPARIAN VEGETATION STRUCTURE		Does the method collect any information on riparian vegetation structure?
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Does the method collect any information on riparian vegetation longitudinal continuity?
	RIPARIAN VEGETATION WIDTH		It refers to the width of functional vegetation in the fluvial corridor; does the method require any information on the lateral extent of riparian vegetation?

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	Does the method give additional information on vegetation species composition (e.g. presence of indigenous, exotic species, etc.) and other characteristics (e.g. species coverage, abundance, riparian soil, etc.)
	ARTIFICIAL FEATURES AND STRUCTURES	It refers to any artificial features located on the banks or in the riparian zones (e.g. bank protections , artificial levees, etc.)
	LAND USE	It refers to the land use presents on banks and in the riparian zone (e.g. roads, houses, farms, cultivated areas, etc.)
D - FLOODPLAIN	FLUVIAL FORMS	Are fluvial forms in the floodplain (e.g. oxbow lakes, wetlands, secondary arms, etc.) recorded?
	INFO ON FLOODPLAIN FEATURES	Is any floodplain features (e.g. floodplain dimension, floodplain soil, etc.) recorded?
	LAND USE	It indicates the land use in the floodplain
4. RIVER PROCESSES		**In this section some information is provided on whether the method explicitly accounts for some physical river processes. In some cases, this type of information could be indirectly derived from other recorded features**
A - LONGITUDINAL CONTINUITY	Sediment and wood	It refers to the longitudinal mobility of sediment and wood
	Water flow	It refers to the longitudinal continuity of water flow
B - LATERAL CONTINUITY	Lateral hydraulic continuity	It refers to the lateral hydraulic connection between the river channel and its riparian zone and/or the floodplain
	Sediment (and wood) lateral continuity	It refers to the sediment and wood continuity (sediment delivery by bank erosion, hillslope-river corridor connectivity, etc.)
C - BANK EROSION / STABILITY		Does the method record the presence and/or extension of eroding banks and/or provide information on bank stability?
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	It refers to adjustments in channel pattern (e.g. from braided to meandering) and channel width (widening, narrowing)
	Vertical	It refers to adjustments in bed elevation (incision, aggradation)
F - VERTICAL CONTINUITY	Groundwater connection	Does the method assess the connection between river and groundwater?
5. APPLICATION TO WFD		**In this section some information on the strengths and applications of each method for the WFD is provided**
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		It is reported whether the method has been officially selected for the implementation of the WFD or is the most commonly used one but is not compulsory
APPLICATION TO ALL WATER BODIES		Is the method used for the classification of all the water bodies?
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It is indicated whether the method is strictly used only for the classification of high status (as required by the WFD) or its use is extended to other classes
USED TO PREDICT RISK OF DETERIORATION		Is the method used to predict the risk of deterioration (following changes in pressures)?
USED TO IDENTIFY IMPROVEMENT TARGETS		Is the method used to predict the effects of restoration measures?
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		Is the method used to identify causes of ecological impacts?
KEY STRENGTHs FOR RIVER MANAGEMENT		E.g. easy to apply, applicability for different lengths of data series, procedure for gauged and ungauged stations, a priori evaluation of pressures, etc.

Appendix E: Description of the methods implemented by European countries for the WFD: 1. Method background; 2. Method characteristics; 3. Recorded features; 4. River processes; 5. Application to WFD (NOT APPLICABLE = not assessed/not considered by the method; NOT AVAILABLE = information not available)

Appendix E 1 – Guidelines for assessing the hydromorphological status of running waters (Austria)

1 - METHOD BACKGROUND			
NAME OR CODE			**Guidelines for assessing the hydromorphological status of running waters**
COUNTRY			Austria
KEY REFERENCE			Mühlmann (2010)
WEBPAGE			http://www.lebensministerium.at/wasser/wasser-oesterreich/plan_gewaesser_ngp/nationaler_gewaesserbewirtschaftungsplan-nlp/hymo_lf.html
CATEGORY			The aim is the overall hydromorphological assessment of rivers following the WFD requirements
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	A preliminary desk study based on existing GIS maps is used to identify the survey reach on the national network (each river having a catchment larger than 10 squared-km has been identified, indexed and reported in a national database - results of the hydromorphological survey method and assessment must be transferred into this national system). The method also uses available maps, aerial photos, and remote sensing techniques in the assessment procedure (photo-interpretation). The manual aids to select the best method to collect data (when use maps and remote sensing and/or when apply field analysis)
		Field survey	The field survey is used to complete the set of information already available from existing database
		Rapid field assessment	NOT AVAILABLE
		Existing database	Existing database represents the core of the data collection for the hymo assessment. Mainly, existent data on human structures must be collected before the survey (i.e. hydroelectric power plants, dams, etc.), as well as existing hydrological data
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The hydrographical network has been subdivided into reaches of 500 m length at the national scale (for catchment larger than 10 squared-km)
	LONGITUDINAL SPATIAL SCALE	Fixed length	The survey must be conducted on segments 500 m long (correspond to segments of the national network)
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Channel is assessed (morphological parameters)
		Banks/Riparian zones	Right and left banks are assessed together (morphological parameters). Riparian vegetation is assessed separately from banks (morphological parameters)
		Floodplain	NOT APPLICABLE
C - TEMPORAL SCALE		Physical and morphological assessment	It assesses the present state
		Hydrological assessment	
D - TYPE OF METHOD		Characterization/classification	The method aims to characterize hydromorphological conditions. 3 groups of parameters: hydrological parameters (intakes, hydro-peaking, impoundments), transversal structures for the assessment of continuity, morphological parameters (main parameters: planform/river course, bank dynamic, bed dynamic; secondary parameters: substrate composition, bed structure, riparian vegetation). Parameters are recorded through presence/absence criteria (e.g. fish passability); by measuring the proportion(%) of reach interested by the feature (e.g. intakes); by measuring them (e.g. water flow velocity); by describing them (e.g. transversal structures); qualitatively assessed in a 5-points class scale (only morphological parameters)
		Assessment by index	Morphological parameters (for channel and banks) are assessed in a 5-point scale from 1 (natural) to 5 (anthropogenic)
		Deviation from reference	NOT AVAILABLE
		General assessment / Design framework	NOT AVAILABLE
		Modelling status / Scenario	NOT AVAILABLE

		Final expert judgment	The expert opinion enters in the assessment procedure for example by integrating their judgment in the evaluation of the impact of intakes and water transfer
		Links with other systems	NOT AVAILABLE
E - REFERENCE CONDITIONS			The method does not refer directly to some reference condition, but considers only rivers where ecological status is classified as high; the high hydromorphological status is defined by the absence or negligible presence of human impacts
F - GENERAL INFORMATION	RIVER TYPOLOGY		Similar to Germany: 26 river types
	TYPOLOGY LIMITATIONS		NOT AVAILABLE
	TYPE-SPECIFIC (Protocol / Assessment method)		The method indicates that the use of aerial photos must be limited to large rivers; for small rivers it is suggested to collect field
	BASIS FOR STANDARDS / THRESHOLDS		The basis for thresholds are defined by the method/authors: thresholds are defined for morphological parameters (classes 1 to 5), as well as for the definition of the high and good hymo status as part of the assessment of ecological status
	REACH SCALE SURVEY STRATEGY		The overall reach or single point-transect are assessed, on the basis of the specific parameter of interest
	TIMING AND FREQUENCY		During low flow and not during vegetative seasons (from November to April)
	DATA PRESENTATION (OUTPUT/LAYOUT)		NOT AVAILABLE
	METHOD SUPPORT / APPLICATION TOOLS		Operational guidelines (manual); field forms
	SPATIAL COMPARISON		NOT AVAILABLE
	CONNECTION TO ECOLOGY		The connection to ecology is direct in the evaluation of the environmental flow (minimum water level and discharge) in fish habitats. The riparian vegetation is evaluated by taking into account the functions it provides to ecosystem (e.g. shading, source of food, buffering from pollutants, etc.)
	USERS		The method is used to support the assessment and monitoring of hydromorphological status in the definition of (high) ecological status for the implementation of the WFD
	SCALE INFORMATION		Reach scale information is mainly provided
	NUMBER OF END PARAMETERS		3 groups of parameters, organised into main and additional/sub-parameters and several indicators: hydrology (3 main parameters), morphology (2 main parameters, 4 additional parameters) and river continuity
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	The method collects and assesses data on hydrological conditions in terms of hydrological regime alteration: intakes, hydro-peaking and impoundment
		Metrics of hydrological regime	Water level, water discharge, runoff characteristics; minimum water level and discharge (environmental flow)
		Hydro-peaking	It is collected/assessed as specific hydrological parameter (main parameter)
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		E.g. straight, meandering, tortuous
	CHANNEL FORMS		E.g. gravel islands, gravel or fine sediment benches, vegetated islands and bars
	BED CONFIGURATION		E.g. bed structures (e.g. riffle/pool sequences)
	CHANNEL DIMENSIONS		NOT AVAILABLE
	FLOW-TYPE		NOT AVAILABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT AVAILABLE
	SUBSTRATE		Substrate composition (megalithal, macrolithal, mesolithal, microlithal, gravel, sand, mud)
	IN-CHANNEL VEGETATION		NOT AVAILABLE
	WOODY DEBRIS		Branches, trees, woody debris
	ARTIFICIAL FEATURES AND STRUCTURES		Water intakes, transfer, hydroelectric power-plants, impoundment; artificial substrate; transversal structures [structures for hydropower (e.g. weirs); structures for flood protection (e.g. dams); other structures for other human purposes (e.g. pipes); natural fall (> 1 m height); structures for riverbed stabilisation]
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Bank dynamics, bank profile
	BANK MATERIAL		Artificial substrate (e.g. concrete, riprap, wood obstruction, bioengineering / engineering and biological materials, groynes, dredging materials)
	RIPARIAN VEGETATION STRUCTURE		Vegetation structure (on banks and channel)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Status of riparian vegetation is assessed for 500 m stretches in a 5-point scale from 1 (natural) to 5 (riparian vegetation missing)

	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		It assesses the status of the riparian vegetation in relation to the service that it provides to ecosystems (e.g. food, shading, etc.) and river dynamic (e.g. preventing erosion, dead wood entry, etc.)
	ARTIFICIAL FEATURES AND STRUCTURES		Embankments; artificial substrate (e.g. concrete, riprap, wood obstruction, bioengineering / engineering and biological materials, groynes, dredging materials)
	LAND USE		NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		NOT APPLICABLE
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	A specific group of parameters focuses on transverse structures affecting longitudinal continuity: structures for hydropower (e.g. weirs); structures for flood protection (e.g. dams); other structures for other human purposes (e.g. pipes); natural fall (> 1 m height); structures for riverbed stabilization. It defines how to assess the passability of those structures
		Water flow	
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Indirectly assessed through the presence of artificial structures and the assessment of riparian vegetation conditions
		Sediment (and wood) lateral continuity	
C - BANK EROSION / STABILITY			Bank dynamics (is a main parameter); bank erosion
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method has been developed by the Federal Ministry of Agricolture, Forestry, Environment and Water Management in collaboration with the 9 Federal provinces (Bundesländern). The objective was to have a standard national method to assess the hydromorphology of rivers to support the assessment of ecological status, according to WFD. It is the official method for Austria
APPLICATION TO ALL WATER BODIES			It has been developed to apply to all water bodies in Austria
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			It is used only for the classification of high status (as required by the WFD), and to assess hydromorphological conditions for rivers which can achieve the good ecological status
USED TO PREDICT RISK OF DETERIORATION			The hydromorphological assessment carried out by this method can be used to predict the risk of deterioration by human impacts on hydromorphology
USED TO IDENTIFY IMPROVEMENT TARGETS			The assessment can be used to identify improvement targets for the hydromorphological component of a river, as well as in those cases in which the good ecological status can be reached
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			The method can be potentially used for this purpose given that it collects data and assesses impacts on hydromorphology linked to biological/ecological responses
KEY STRENGTHS FOR RIVER MANAGEMENT			It provides strong links to ecology; it uses a standard procedure (for Austrian territory). It complies with WDF requirements

Appendix E 2 – HEM (Czech Republic)

1 - METHOD BACKGROUND			
NAME OR CODE			**HEM - Hydromorphological monitoring**
COUNTRY			Czech Republic
KEY REFERENCE			Langhammer (2007)
WEBPAGE			http://www.ochranavod.cz/cz/voda
CATEGORY			The aim is to evaluate the hydromorphological characteristics of rivers in accordance to CEN standards
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	The method uses historical maps to compare the present state to the state before the industrial development
		Field survey	Field mapping (and scoring). Depending on indicator: direct measures (e.g. width), estimation of % (range, e.g. variability of the longitudinal profile), presence/absence
		Rapid field assessment	NOT APPLICABLE
		Existing database	Data from existing databases are used in the assessment (rating) protocol. Hydrological data series are used to assess hydrological changes
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method assesses single features, then attributes a score to each river zone (main groups of parameters), and then assigns a final score to the reach. Several scores for several reaches can be used (averaged) to obtain a final value for the water body
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	10m width = 100m long; 30m width = 500m long; > 30m width = 1 km
		Variable length	The main criterion is to identify homogenous flow reaches and homogenous floodplain characters. If the reach is too long, the criterion "length vs. width" is applied
	LATERAL SPATIAL SCALE	Channel	Channel pattern and channel bed
		Banks/Riparian zones	Left and right banks assessed separately. Riparian area is assessed in a strip of 50m wide
		Floodplain	All the floodplain width is assessed
C - TEMPORAL SCALE		Physical and morphological assessment	It assess the present states, but makes comparison (and maps) to the state before the industrial age
		Hydrological assessment	Average daily and annual flow
D - TYPE OF METHOD		Characterization/classification	The method makes firstly a feature mapping (frequency or extent) and then it rates features
		Assessment by index	The rating system is based on the principle of individual scoring parameters, evaluated from the perspective of their impact on stream hydromorphological quality. Then it calculates the partial hymo quality score for each zone/main group of parameters (4 sub-indices); parameters are weighted to emphasize the influence of key indicators on hymo conditions; then it attributes a final index, the HMK (averaging 4 sub-index) to the reach. The hymo quality of a water body (HMKvu) corresponds to the average of hymo quality of its reaches, weighted by their length
		Deviation from reference	The method assesses the deviation from potential natural flow conditions
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	The scoring system (for each indicator) is defined by experts; weighting parameters for indicators assessment are settled by the authors
		Links with other systems	NOT APPLICABLE
E - REFERENCE CONDITIONS			The highest hydromorphological quality corresponds to a potential natural flow conditions with the highest variability. The reference condition state is defined as: 1) totally or near totally undisturbed conditions in terms of flow regime (quantity and dynamic) and connection to GW; 2) natural flow longitudinal continuity conditions (sediment, flow and organisms); 3) Riverbed/banks/riparian zones conditions and structures correspond totally or nearly totally to undisturbed conditions (hymo quality value close to 1 and not higher than 1.7)
F - GENERAL INFORMATION	RIVER TYPOLOGY		NOT AVAILABLE (Similar to Germany: 53 river types)
	TYPOLOGY LIMITATIONS		NOT AVAILABLE
	TYPE-SPECIFIC (Protocol / Assessment method)		NOT AVAILABLE

	BASIS FOR STANDARDS / THRESHOLDS		Indicators are scored on a 1-5 scale (1 the best, 5 the worst), in comparison to the potential natural flow conditions; values are based on expert judgment, field validation and comparison with analogous methodologies available. Values are weighted to emphasize the relative importance of indicators to determine hymo conditions; weighting values are settled by author. The score for water body is also weighted by the length of the included reaches. The final index allow to a 5 class classification of hymo quality state
	REACH SCALE SURVEY STRATEGY		All the selected reach is assessed including its floodplain (riparian zone within 50m from the channel)
	TIMING AND FREQUENCY		It is recommended to apply method in low flow period and every 6 years
	DATA PRESENTATION (OUTPUT/LAYOUT)		Maps showing the scoring values
	METHOD SUPPORT / APPLICATION TOOLS		HEM field mapping (monitoring) methodology (Langhammer, 2007) and HEM scoring system (Langhammer, 2008)
	SPATIAL COMPARISON		NOT AVAILABLE
	CONNECTION TO ECOLOGY		The method is used to support the assessment of ecological status (survey and monitoring) of rivers
	USERS		The method is used to support the assessment and monitoring of ecological status for the implementation of the WFD
	SCALE INFORMATION		Method collects/provides info only at the reach scale
	NUMBER OF END PARAMETERS		17 parameters organised into 4 main groups: channel pattern (5), channel bed (4), riparian and floodplain zones (4), hydrological regime (4)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	Hydrological conditions/characters (waterfall, cascade, tidal stream, pools, backwaters); influence on the hydrological regime (unchanged, periodic backwater, flow control, abstraction) and water flow conditions
		Metrics of hydrological regime	Flow variability/variation (average daily and annual flow, minimum 3 years period)
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Channel pattern conditions (braided meandering, straight, etc.) at present and in the past, variability of channel width
	CHANNEL FORMS		Variability of depth in the cross section (high, medium, natural/related to channelization, low); channel bed structures (islands, not structures, etc.)
	BED CONFIGURATION		Variability in the longitudinal profile (% range, artificially increased/reduced); channel bed morphology (pools, rapids, etc.)
	CHANNEL DIMENSIONS		Channel width (max & min); variability of channel width; Variability of depth in the cross section
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Channel bed substrate (boulders --> clay, peat, artificial)
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		Dead wood in the channel (number, range)
	ARTIFICIAL FEATURES AND STRUCTURES		Channel bed conditions (reinforcement, culvert, artificial sediment input, no evidence of artificial impact, etc.); Longitudinal continuity conditions (dams, weirs, fish passages)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Variability of depth in the cross section (high, medium, natural/related to channelization, low)
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		River bank vegetation structure (high herbs, shrubs, trees, no vegetation on banks)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Intermittent vegetation belts
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACT.		Natural forest, economic forest, galleries vegetation
	ARTIFICIAL FEATURES AND STRUCTURES		Bank conditions (gabions, blocks, reinforcement, any evidence of impact, etc.); Variability of depth in the cross section (high, medium, natural/due to channelization, low)
	LAND USE		Riparian zone land use (forest, meadow, pasture, Lakes, agricultural area, urban, industrial)
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Floodplain land use (forest, meadow, pasture, Lakes, agricultural area, urban, industrial)

4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	Longitudinal continuity conditions (dams, weirs, fish passages)
	Water flow	Longitudinal continuity conditions (dams, weirs, fish passages)
B - LATERAL CONTINUITY	Lateral hydraulic continuity	Continuity with floodplain (number and/or % of buildings along the river, levees, embankments, longitudinal dykes)
	Sediment (and wood) lateral continuity	NOT APPLICABLE
C - BANK EROSION / STABILITY		NOT APPLICABLE
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	River planform modification (straightening, widening, historical conditions, etc.)
	Vertical	Variability in the longitudinal profile (% range, artificially increased/reduced)
F - VERTICAL CONTINUITY	Groundwater connection	Water abstraction is assessed. Groundwater connection is also taken into account in the definition of reference sites
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		It was recommended as a standard method for hydromorphological surveying by the Ministry of Environment in the Czech Republic in 2008 (Matouskova et al., 2010), based on the EN 14614 standard
APPLICATION TO ALL WATER BODIES		The method seems to be applied to all water bodies at least in CR
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It is used in the classification of high/reference biological status in the absence of reference sites
USED TO PREDICT RISK OF DETERIORATION		Given that it is adopted used in the monitoring programs, it could be used to predict the risk of deterioration
USED TO IDENTIFY IMPROVEMENT TARGETS		It is used in monitoring programs
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		The method has been developed to support hymo quality assessment for the classification of ecological status: it has been applied in priority at sites/water bodies where ecological data were available
KEY STRENGTHS FOR RIVER MANAGEMENT		It complies with WFD requirements; both mapping/inventory and assessment protocols/phases; it is based on expert knowledge (low subjectivity)

Appendix E 3 – DHQI (Denmark)

1 - METHOD BACKGROUND			
NAME OR CODE			**DHQI - Danish Habitat Quality Index**
COUNTRY			Denmark
KEY REFERENCE			Pedersen & Baatrup-Pedersen (2003); Pedersen et al. (2006)
WEBPAGE			http://www.dmu.dk/nyheder/artikel/forslag_til_fysisk_indeks_for_vandloeb/
CATEGORY			The method has been formerly developed to add components of physical habitat to environmental impact/state assessment and setting target in catchment plans
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Remote sensing information (e.g. land cover, geology etc.) is collected, in the former version, during the first part of the method protocol ("Site protocol") which aims to characterize the survey site. However they don't enter in the assessment index
		Field survey	The "assessment protocol" consists in classifying features based on their presence or frequency. Features are assessed using 3 classes of frequency; parameters are the same in the former and recent versions (in the former version, some features of the "site protocol" were recorded during the field survey and entered in the index calculation). Field parameters are separated into 3 categories: reach, in-stream and substrate parameters
		Rapid field assessment	The method makes use of a rapid field assessment protocol
		Existing database	NOT APPLICABLE
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The index assesses the physical habitat quality at the reach scale
	LONGITUDINAL SPATIAL SCALE	Fixed length	The length to be assessed is 100 meter for small rivers, and 200 m for large rivers
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Channel features are recorded for the most part during the field "assessment protocol"
		Banks/Riparian zones	Bank and riparian zone features are recorded for the most part during the filed "assessment protocol"
		Floodplain	Floodplain features (i.e. land use) are only recorded (but not assessed) up to 50 m of the riparian zone
C - TEMPORAL SCALE		Physical and morphological assessment	The method assesses the present state of a river reach
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method characterizes the surveyed site through the "Site protocol" (at least in the former version)
		Assessment by index	The "assessment protocol" aims to obtain a final assessment index: 3 scores/intensity classes are possible for each parameters (4 in the former version). The score/intensity class is then weighted to the relative importance of the parameters. The final index is the sum of single sub-scores (given by the product between intensity and weight). The final index generates 5 habitat quality classes
		Deviation from reference	NOT AVAILABLE
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	The method is used in the National Monitoring Programme
E - REFERENCE CONDITIONS			The method refers to known reference sites but it is unclear how the reference conditions for the physical environment have been established. Data on reference sites have been used to set-up limits between quality classes
F - GENERAL INFORMATION	RIVER TYPOLOGY		The method relates to a river typology in according to the implementation of the Water Framework Directive (System A)
	TYPOLOGY LIMITATIONS		The method is applicable to lowland river types (small and large rivers). The first version of the method was limited only to small lowland rivers. Probably it cannot be applied to large rivers where high flow depth prevents the assessment of bed conditions
	TYPE-SPECIFIC (Protocol / Assessment method)		The method applies the same protocol to small and large rivers; the only difference is the length of the assessed reach (100/200 m)

	BASIS FOR STANDARDS / THRESHOLDS		Data on reference and disturbed sites have been collected to set-up quality classes. The final score ranges from −12 to 63: -12÷0 bad; 0÷13 poor; 14÷25 fair; 26÷38 good; >38 high
	REACH SCALE SURVEY STRATEGY		A representative site is selected and assessed along all the defined length (100 or 200 m)
	TIMING AND FREQUENCY		The method has been developed to limit the time spent in the field to a maximum of one hour
	DATA PRESENTATION (OUTPUT/LAYOUT)		Main characteristics and the evaluation results are inserted into a GIS database; photos are also compiled for each surveyed reach
	METHOD SUPPORT / APPLICATION TOOLS		The survey data and the evaluation results are documented in standardised forms and field maps. The site protocol is accompanied by a protocol with description of parameters (by graphs, pictures and drawings)
	SPATIAL COMPARISON		Parameters in the habitat index are assessable in most wadable streams, therefore the evaluation of the physical habitat quality can be carried out for different types of lowland streams
	CONNECTION TO ECOLOGY		The connection to ecology is not direct but the method is used in National Monitoring Programme for rivers and stream. The method could potentially evaluate habitat changes (info on substrates, flow velocity, riffle-pool, etc.)
	USERS		Field training is required but no accreditation procedures have been implemented
	SCALE INFORMATION		Information is collected at both large and local spatial scales, but only reach-scale features/information are used to calculate the assessment index
	NUMBER OF END PARAMETERS		Formerly: 20 parameters collected through the "site protocol" (map/remote sensing and field); 17 parameters collected into the field during the "assessment protocol"; 25 parameters entered formerly in the assessment index. The recent development of Pedersen et al. (2006) indicates 17 parameters into the final index
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		In the "site protocol": stream order, geology, catchment area, distance to source, soil type, altitude, highest/lowest catchment points, catchment organic pollution, weed cutting – at present, etc.
	HYDROLOGICAL REGIME	Hydrological conditions	NOT APPLICABLE
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		River valley form ("site protocol")
B - CHANNEL	CHANNEL PATTERN / PLANFORM		General "channel plan form" was recorded only in the "site protocol" in the former version (classes) but in the recent version it is assessed in the reach section; meandering is recorded in both versions
	CHANNEL FORMS		NOT APPLICABLE
	BED CONFIGURATION		Riffles and pools are assessed
	CHANNEL DIMENSIONS		Stream width (during the "site protocol"); Variation in depth (only in the former version); Variation in width
	FLOW-TYPE		High energy flow velocity
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Coverage of stones/gravel/sand/mud on stream bed
	IN-CHANNEL VEGETATION		Both emergent and submerged vegetation are recorded
	WOODY DEBRIS		Presence of LWD and large stones (only in the former version); Roots in the stream
	ARTIFICIAL FEATURES AND STRUCTURES		In the recent version physical variations are recorded in the in-stream section
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Cross section is assessed
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		NOT APPLICABLE
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		Width of natural vegetation in the riparian areas
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Indirectly assessed through the evaluation of the cross section
	LAND USE		NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE

LAND USE		Land use in the river valley up to 50 m of distance from the stream (% of 12 classes, through the "site protocol" in the former version)
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	NOT APPLICABLE
	Water flow	NOT APPLICABLE
B - LATERAL CONTINUITY	Lateral hydraulic continuity	NOT APPLICABLE
	Sediment (and wood) lateral continuity	This information could be in part obtained through knowledge of weed management (weed cutting – at present; changes in weed cutting procedure during past 5 years)
C - BANK EROSION / STABILITY		Bank erosion is assessed in the "site protocol" in the former version and in the reach section of the field protocol in the recent version
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method is the evolution of the Aahrus method (Kaarup, 1999). The method is officially used in the National Monitoring programme for rivers and streams. In the recent version of Pedersen et al. (2006), the author suggests that the new index should be included as a quality element in the implementation of WFD
APPLICATION TO ALL WATER BODIES		The method applies only to lowland streams and rivers given that it has been developed for Danish water bodies; it does apply neither to HMWBs nor to AWBs
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		NOT AVAILABLE
USED TO PREDICT RISK OF DETERIORATION		NOT APPLICABLE
USED TO IDENTIFY IMPROVEMENT TARGETS		Indirectly, given that the method is used in the national monitoring programme
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		NOT APPLICABLE (given that pressures are not deeply assessed)
KEY STRENGTHS FOR RIVER MANAGEMENT		Easy and rapid to apply

Appendix E 4 – RHS (England and Wales)

1 - METHOD BACKGROUND			
NAME OR CODE			**RHS – River Habitat Survey**
COUNTRY			England and Wales
KEY REFERENCE			Raven et al. (1997)
WEBPAGE			http://www.environment-agency.gov.uk/research/library/publications/123383.aspx
CATEGORY			It is a method designed to characterize and assess, in broad terms, the physical structure of freshwater streams and rivers (physical habitat assessment). Its primary objective is to allow a context-setting, but it can be also used in general surveillance as well as site specific survey
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	The method does not directly use maps and Remote Sensing analysis
		Field survey	The method records information (presence/absence criteria) st 2 scales of analysis: the first focuses on general river characteristics, the second is more detailed on habitats characterization. Only some information concerning large scale characteristics is collected
		Rapid field assessment	The method could be a rapid field assessment method only for well-trained operators
		Existing database	The method uses existing database on reference sites
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Analyses are carried out at the site scale (SWEEP-UP) and for representative transect 10 m wide (SPOT-CHECK)
	LONGITUDINAL SPATIAL SCALE	Fixed length	The method uses a fixed length, the reach SWEEP-UP = 500 m. Observations are made at 10 SPOT CHECK = 10 m wide, equally spaced
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	The physical attributes of the channel (called wetted channel area) are entirely assessed in a 1 m wide transect (within the Spot-check)
		Banks/Riparian zones	Some characteristics (vegetation) are recorded at the bank face and within 1 m on banktop (Spot-Check)
		Floodplain	Some characteristics (bank profile, land use) are recorded within 5-50 m in the floodplain (Sweep-up)
C - TEMPORAL SCALE		Physical and morphological assessment	No historical data are used. Because of the parameters which are measured, it is not possible to add historical states of sites to the database
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method characterizes in detail physical features and makes also an inventory of some features, e.g. channel forms, bed morphology (n. of pool and riffle), artificial features, etc.
		Assessment by index	The method is developed to obtain 2 different final indexes: Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS)
		Deviation from reference	Calibration of habitat quality is obtained by comparison with reference sites surveyed using RHS and previously scored by experts judgment (as reference sites for the UK)
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	The method does not provide and/or use models, but data collected could be potentially used for the application of habitat models
		Final expert judgment	Habitat Quality Assessment reflects the diversity of natural features based on expert opinion
		Links with other systems	The method could be used in conjunction with RIVPACS; it also collects information required by SERCON (System for Evaluating Rivers for Conservation)
E - REFERENCE CONDITIONS			Data collected and included in the database are used for the definition of the deviation from reference conditions through a *"a posteriori"* statistical approach; reference sites have been identified by experts
F - GENERAL INFORMATION	RIVER TYPOLOGY		Typology is based on cluster analysis of all sites in the initial dataset: clusters were evaluated by experts and tested in the field to determine the end-typologies used
	TYPOLOGY LIMITATIONS		The method in itself (original version) is mainly applicable to relative low energy systems, mostly single-thread and transitional systems, not to temporary systems and large rivers

	TYPE-SPECIFIC (Protocol / Assessment method)		A different protocol/method has been lately developed for Urban streams (URS, Davenport et al., 2004)
	BASIS FOR STANDARDS / THRESHOLDS		The HQA is divided in 5 classes (from 1=very good (reference) to 5=bad); the HMS is in 6 different classes (from 0=pristine to > 45 = severely modified). The classification is based on quintile divisions derived from the reference sites score (obtained by the application of the RHS)
	REACH SCALE SURVEY STRATEGY		10 representative sites (Spot-checks within a 500m reach)
	TIMING AND FREQUENCY		About 1 hour for the field survey per site (experienced surveyors who have received two days of training); poor repeatability of the method through time
	DATA PRESENTATION (OUTPUT/LAYOUT)		The method provides: data to entry in the database; an index of habitat quality (HQA); a scoring system to assess the habitat modification (HMS); all data in the RHS database can also be visualised through use of GIS
	METHOD SUPPORT / APPLICATION TOOLS		It does exist a RHS database where all surveys accomplished with the method are entered; there are also booklets available with examples and photos of features to be scored; the method uses a field compilation form
	SPATIAL COMPARISON		The system relies on comparison of sites for the scoring system of quality (same type); habitat modification system is not linked to a specific river type
	CONNECTION TO ECOLOGY		The method could supply a framework to set biological surveys
	USERS		The method does not require specialist geomorphological or botanical expertise, but recognition of vegetation types and an understanding of basic geomorphological principles and processes are needed; training is mandatory for surveyors
	SCALE INFORMATION		The method is applicable at individual site level, it gives only few information at larger spatial scales; multiple sites can be combined into water body data
	NUMBER OF END PARAMETERS		63 parameters (+sub parameters) divided into 15 categories
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Altitude; slope; geology; height of source; valley form; distinct flat valley bottom; natural terraces
	HYDROLOGICAL REGIME	Hydrological conditions	The method checks only the flow conditions at the time of observation
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		Predominant valley form; distinct flat valley bottom; natural terraces
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE (but, indirectly, it records for example the number of sub-channels for braided rivers, point bar characteristics for meandering rivers)
	CHANNEL FORMS		Not visible, none, exposed bedrock --> mature island, trash (urban debris) + presence of e.g. side channels, backwaters
	BED CONFIGURATION		The number of pools and riffles; the presence of waterfalls and cascades
	CHANNEL DIMENSIONS		Banks (height, embanked height, etc.); channel (depth, width, etc.); trashline; extent of channel and bank features
	FLOW-TYPE		Not visible, free fall --> smooth, no perceptible, no flow (dry)
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Only substrate type is recorded: not visible, bedrock --> clay, peat, earth, artificial; consolidation of bed material
	IN-CHANNEL VEGETATION		Mosses/lichens, emergent broad-leaved, submerged broad/linear/fine-leaved, amphibious, etc.
	WOODY DEBRIS		LWD extension, debris dam, leafy debris
	ARTIFICIAL FEATURES AND STRUCTURES		Not know, none, culverted, resectioned, dam, etc.
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Eroding/stable cliff, point bars, side bars, bank profile (natural, artificial)
	BANK MATERIAL		Not visible, natural (bedrock --> clay), artificial (concrete --> bio-engineering materials)
	RIPARIAN VEGETATION STRUCTURE		Bare, uniform --> complex
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		None, isolated/scattered --> continuous; and associated features (shading of channel, fallen trees, etc.)
	RIPARIAN VEGETATION WIDTH		The method assess the land use within 5 and 50 m of banktop, therefore indirectly are given some information about the riparian vegetation width
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Presence of notable nuisance plan species; presence/extent and state of alders

	ARTIFICIAL FEATURES AND STRUCTURES		Bank modifications (not known, none, resectioned, embanked, etc.)
	LAND USE		Land use within 5 m of banktop (woodlands, plantation, orchard, urban development, artificial open water, park, etc.)
D - FLOODPLAIN	FLUVIAL FORMS		Natural/artificial open water, wetland (marsh, fen, etc.)
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Land use within 5 and 50 m of banktop (woodlands, plantation, orchard, urban development, artificial open water, park…)
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	The assessment of artificial features in the channel and on the banks could be indirectly used to assess the potential longitudinal mobility of sediment
		Water flow	The assessment of artificial features in the channel could be indirectly used to assess the potential longitudinal mobility of sediment (but not to evaluate hydrological alterations)
B - LATERAL CONTINUITY		Lateral hydraulic continuity	It could be indirectly assessed (presence of fluvial forms in the floodplain)
		Sediment (and wood) lateral continuity	It could be in part indirectly assessed by for example the presence of bank modification (embankment) and land use. Hillslope-river corridor continuity and potentially erodible corridor are not assessed
C - BANK EROSION / STABILITY			Bank profiles (slope) and bank features (eroding/stable cliff) from a qualitative point of view
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	Indirectly assessed: Fen(s) and Flush(es) assessed as "features of special interest"
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method is the most commonly used in England and Wales since 2000s in combination with aerial photo assessment and GIS datasets of flood defence infrastructure. The method development has been influenced by the WFD: the prototype was developed in anticipation of the requirements of the WFD. It allowed to collect hydromorphological data within the European STAR-project
APPLICATION TO ALL WATER BODIES			The method applies to all water bodies in England and Wales. Modifications of the original method allowed the possibility to apply the method to EU-southern water catchments (SE-RHS, CARAVAGGIO, adaptation in Portugal)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			It has been used in the River Basin Characterization Project I, 2004 (RBC1) and in the Technical Assessment method for rivers: morphological alteration, Environment Agency. It has been used to help identify reference conditions, “heavily modified” riverine water bodies
USED TO PREDICT RISK OF DETERIORATION			It has been used, through HMS, to assess the risk of habitat deterioration (EA, Technical assessment method, Hydromorphology project) and to help in identifying hydromorphological pressures affecting river catchments
USED TO IDENTIFY IMPROVEMENT TARGETS			It can be potentially used for this purpose
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			Indirectly, relating habitat information to biological sampling; it can be used for the analysis of habitat suitability
KEY STRENGTHS FOR RIVER MANAGEMENT			It has specifically been developed to respond and to test WFD requirements. It is able to detect local variations in features contributing to habitat character (Raven et al., 2002)

Appendix E 5 – CarHyCE (France)

1 - METHOD BACKGROUND			
NAME OR CODE			**CarHyCE - CARactérisation HYdromorphologique des Cours d'Eau**
COUNTRY			France
KEY REFERENCE			Onema (2010)
WEBPAGE			http://www.eaufrance.fr/spip.php?rubrique87/
CATEGORY			The method aims to characterize the hydromorphology of rivers (physical components)
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	NOT APPLICABLE
		Field survey	The field survey protocol measures several physical variables at the reach (transects) scale
		Rapid field assessment	NOT APPLICABLE
		Existing database	NOT APPLICABLE
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Analyses are conducted only at the reach scale of the Surveillance Monitoring network reaches; those reaches are selected as representative of the French range of river types
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	The reach length corresponds to 14 times the bankfull width (1.5/2 years return period)
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Several parameters (e.g. characterizing hydraulic geometry, bed configuration, etc.) are measured in the channel, at 15 equally-spaced transects
		Banks/Riparian zones	Banks and riparian areas are more qualitatively characterized; riparian characteristics are recorded at a strip 1/2 bankfull width long
		Floodplain	NOT APPLICABLE
C - TEMPORAL SCALE		Physical and morphological assessment	Only the present status is characterized
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method aims to collect data to objectively characterize the hydromorphological aspects of rivers; these data are then entered into a web database available for further purposes
		Assessment by index	NOT APPLICABLE
		Deviation from reference	NOT APPLICABLE (but potentially assessed, given that the protocol has also been applied to reference sites)
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	The method could be applied in conjunction with SYRAH, the national database on hydromorphological impacts at the catchment scale, as well as together with ROE&ICE protocols, which give information on the longitudinal continuity. Finally, collected physical data could be useful for the calculation of the IAM (Index of Morphodynamic Attractiveness, De Giorgi et al., 2002)
E - REFERENCE CONDITIONS			The protocol has also been applied to the reference sites network (RSR) which corresponds to very low impacted sites, allowing comparison between unmodified and impacted hydromorphological characters of river reaches. Reference sites are selected on the basis of hydro-ecoregions and river types where possible, otherwise modelled and/or defined by expert judgment
F - GENERAL INFORMATION	RIVER TYPOLOGY		Reference sites have been selected for each hydro-ecoregion and each river type
	TYPOLOGY LIMITATIONS		The method could be applied to all river types in France
	TYPE-SPECIFIC (Protocol / Assessment method)		NOT APPLICABLE
	BASIS FOR STANDARDS / THRESHOLDS		NOT APPLICABLE
	REACH SCALE SURVEY STRATEGY		Measures are taken at 15 equally-spaced transects in the selected river reach; cross profile bed elevation and substrate are also recorded at each interval of 1/7 of channel width
	TIMING AND FREQUENCY		NOT APPLICABLE
	DATA PRESENTATION (OUTPUT/LAYOUT)		Several raw data on physical and hydrological characteristics of river reaches (models, analysis, etc.). Integration into a national database (NAIADES, Banque nationale de données sur la qualité des eaux de surface continentales)

	METHOD SUPPORT / APPLICATION TOOLS		A technical guide will be available soon
	SPATIAL COMPARISON		Comparison between rivers of the same type are allowed, and also to compare the quality status at the French national scale
	CONNECTION TO ECOLOGY		Reaches of the Surveillance Monitoring network, where CarHyCE has been formerly applied, have also been selected because of the presence of available historical data on fish communities, to allow comparison between hymo and ecological/biological data. The method could support information for the calculation of the IAM (De Giorgi et al., 2002)
	USERS		The method has been developed to be used for management/conservation purposes, but collects/uses methods coming from the scientific field
	SCALE INFORMATION		Only information at the local scale is provided (reach and station)
	NUMBER OF END PARAMETERS		NOT AVAILABLE
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	The method measures the bankfull discharge and stage as well as the flow rate during the survey
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE
	CHANNEL FORMS		The method measures cross section topography at each 1/7 of the bankfull width
	BED CONFIGURATION		The method measures cross section topography at each 1/7 of the bankfull width and channel slope; the method characterizes bed configuration (facies d'écoulement)
	CHANNEL DIMENSIONS		Bankfull width and stage, wetted channel width, water depth, etc.
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		Unit stream power, hydraulic geometry, modelling roughness (from grain size measurements)
	SUBSTRATE		Size classes at transects (index of grain size diversity); clogging (8 measures per reach); measure of sediment size at runs (100 random points); organic substrates
	IN-CHANNEL VEGETATION		Considered as organic habitat
	WOODY DEBRIS		Considered as organic habitat
	ARTIFICIAL FEATURES AND STRUCTURES		NOT APPLICABLE
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Banks height as well as cross profiles + characteristic bank habitats (refugia, exposed roots, etc.)
	BANK MATERIAL		Artificial, rip rap, etc.
	RIPARIAN VEGETATION STRUCTURE		Named "layers"
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Longitudinal continuity of riparian vegetation
	RIPARIAN VEGETATION WIDTH		Named "thickness"
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Natural, allochtonous vegetation
	ARTIFICIAL FEATURES AND STRUCTURES		Artificial bank materials
	LAND USE		NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		NOT APPLICABLE
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	The potential longitudinal mobility of sediment is assessed through unit stream power combined with sediment size measurement (determining the sediment transport capacity of the river)
		Water flow	NOT AVAILABLE
B - LATERAL CONTINUITY		Lateral hydraulic continuity	NOT AVAILABLE
		Sediment (and wood) lateral continuity	NOT AVAILABLE
C - BANK EROSION / STABILITY			The mean bankfull width/depth ratio provides information on erosional/stability processes characteristics of banks, as well as the unit stream power provides information on the capacity of the river to erode its banks
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE

F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method aims to characterize rivers at the station/reach scale, to allow the hydromorphological monitoring for the Surveillance Monitoring network as required by the WFD. The method will be used as the official one for the implementation of the WFD (determine the quality elements for hymo) but a scoring system is under development
APPLICATION TO ALL WATER BODIES		The method applies to all water bodies in France
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		One of the objectives of the method is also to support the planning of conservation programmes for good and high-status water bodies
USED TO PREDICT RISK OF DETERIORATION		NOT APPLICABLE
USED TO IDENTIFY IMPROVEMENT TARGETS		The method could represent a tool to support and assess the restoration projects/actions
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		NOT APPLICABLE
KEY STRENGTHS FOR RIVER MANAGEMENT		The objective characterization of river hydromorphology represents the most important strength (several further applications)

Appendix E 6 – SYRAH-CE & AURAH-CE (France)

1 - METHOD BACKGROUND			
NAME OR CODE			**SYRAH-CE & AURAH-CE - Système Relationnel d'Audit de l'Hydromorphologie des Cours d'Eau & AUdit RApide de l'Hydromorphologie des Cours d'Eau**
COUNTRY			France
KEY REFERENCE			Chandesris et al. (2008); Valette et al. (2010)
WEBPAGE			http://www.irstea.fr/la-recherche/unites-de-recherche/maly/pole-onema-irstea/hydromorphologie-et-alterations-physiques; http://www.onema.fr/-Diagnostiquer-les-alterations-
CATEGORY			The aim is to provide an audit system to make an inventory and analyze all hydromorphological alterations/impacts of water courses at the national scale. It is morphological, process-oriented framework
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	The method is mainly based on existing maps (e.g. land cover, cartographic, geological, soil erosion maps, etc.) and the uses of GIS techniques
		Field survey	The AURAH-CE protocol collects complementary info (artificial structures) to SYRAH-CE on the field (and permits to validate GIS based analysis of SYRAH)
		Rapid field assessment	AURAH-CE is named to be a "Rapid tool" for the field inventorying of artificial structures (not valid for large rivers)
		Existing database	The method uses existing data from databases (e.g. on human activities on the territory)
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	It uses a multi-scale approach, focusing firstly on catchment spatial processes: it uses a "top-down" approach where large scale damage risk assessment serves to focus analysis of alteration on the lower levels (structure, processes and habitats). Rivers are segmented into homogenous geomorphic reaches, and then into spatial units (USRA). Finally, AURAH-CE is applied at the reach scale, where reaches are randomly selected
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	AURAH-CE reaches are long proportionally to channel width
		Variable length	It uses homogenous geomorphic reaches within which data are collected at smaller spatial units of data collection and analysis (USRA)
	LATERAL SPATIAL SCALE	Channel Banks/Riparian zones Floodplain	Land use, activities and artificial structures are collected at the channel, bank and riparian zone, and floodplain scales, on several buffers from the channel: 5 m, 3 times the channel width, and 10 times the channel width, respectively. AURAH-CE collects info mainly on the channel, but also on the banks and riparian area
C - TEMPORAL SCALE		Physical and morphological assessment	It collects data at the present time but collects also evidence of channel evolution
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method serves to developed a national database on hymo structures (impacts) on rivers and streams
		Assessment by index	NOT APPLICABLE
		Deviation from reference	NOT APPLICABLE
		General assessment / Design framework	It uses an environmental risk assessment logic (DPSIR) and an auditing instead of an evaluation protocol; it produces risk maps based on the location and intensity (extent) of artificial structures and the severity of their effect on ecosystem
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	SYRAH-CE and AURAH-CE are distinct protocols which can be combined to get national and local spatial scale information on hymo alteration. SYRAH-CE could represent a database for other systems, such as ROE-ICE and CarHyCE
E - REFERENCE CONDITIONS			NOT APPLICABLE
F - GENERAL INFORMATION	RIVER TYPOLOGY		Rivers are grouped into homogenous rivers typologies following large scale characteristics (HER, geology, valley features, hydrological network)
	TYPOLOGY LIMITATIONS		NOT APPLICABLE
	TYPE-SPECIFIC (Protocol / Assessment method)		The assessment of physical alteration is done as function of the geographical domain (i.e. mountain vs. plain): for example, bedload sediment deficit (barriers, mining) is not analyzed where slope is low than 4%

	BASIS FOR STANDARDS / THRESHOLDS		NOT APPLICABLE
	REACH SCALE SURVEY STRATEGY		SYRAH-CE records artificial structures at sub-reaches scale (spatial units), at different buffer widths. AURAH-CE collects info by walking along the selected river reach and takes measures at specific points (on the basis of the method adopted)
	TIMING AND FREQUENCY		AURAH-CE needs at mean 1h per reach
	DATA PRESENTATION (OUTPUT/LAYOUT)		Data are presented on map format: risk maps (sediment flux, flow, morphology alteration) as well as density map (of weirs, of embankment, etc.), and high spatial definition maps from AURAH-CE
	METHOD SUPPORT / APPLICATION TOOLS		Several manuals are available: principles and methods of the protocol SYRAH-CE (Chandsresis, 2008), principles and methods for river segmentations (Valette et al., 2008); the Atlas SYRAH-CE (Chandesris, 2009); protocol AURAH-CE (Valette et al., 2010, with field table-sheets to collect field data)
	SPATIAL COMPARISON		The method allows spatial comparison at the national scale
	CONNECTION TO ECOLOGY		It is not direct but the basic assumption is that hymo control variables determine the ecological status of water bodies
	USERS		It provides aid for management decision and functional restoration of water bodies. The application of AURAH-CE protocol needs sufficient knowledge in hydromorphology
	SCALE INFORMATION		It provides either large scale info/data (SYRAH-CE) and local scale data (AURAH-CE)
	NUMBER OF END PARAMETERS		SYRAH-CE assesses the risk of flow (3-5 parameters), sediment flux (3 parameters) and morphological (6 parameters) alterations. AURAH-CE analyses/measures pressures (5 parameters) and alterations (4 parameters)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Info on activities and land cover/use at catchment scale are combined and used to guide the risk assessment at lower levels. Geology (substrate), HER, altitude are used to make the former sectorization of the river in homogenous reaches
	HYDROLOGICAL REGIME	Hydrological conditions	Hydrological network is used to make the former sectorization of the river in homogenous reaches. The method assesses the risk of hydrological alteration
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	It assesses the risk of hydropeaking (globally in the hydro alteration)
	VALLEY FORM / FEATURES		Valley form and features (width, slope) are used to make the former sectorization of river in homogenous reaches
B - CHANNEL	CHANNEL PATTERN / PLANFORM		River straightening (river tot length/river bird's eye length)
	CHANNEL FORMS		NOT APPLICABLE
	BED CONFIGURATION		AURAH-CE collects and measures bed configuration characteristics (facies, e.g. lentic/lotic conditons, rapid, run, pool, riffle, etc.)
	CHANNEL DIMENSIONS		Examples of measures: Ratio of channel water surface reconstructed/observed; proportion of channel shortened; proportion of channel interested by water intake. AURAH-CE measures bankfull elevation and width
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		AURAH-CE collects qualitative information on substrate composition (along riffles) and clogging (qualitative classes)
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Dams, weirs, by passed sections, resectioning, bridges, etc. AURAH-CE identifies/measures and characterizes evidences of sediment mining/dredging; it also characterizes (age, general measures, features, etc.) artificial structures (bridge, dam, weir, deflectors, etc.)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		NOT APPLICABLE
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Alteration of riparian vegetation structure/presence (e.g. available surface/river corridor surface)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Lack of riparian forest
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES	Riparian zone artificialization, embankment, resectioning, dikes, stabilisation, channelization, levees, etc. AURAH-CE characterizes (material, age, orientation, distance from channel, etc.) and measures embankments, as well as bank protections
	LAND USE	Intensive farming, gravel mining, roads, plantations, etc.
D - FLOODPLAIN	FLUVIAL FORMS	Water bodies
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	The method gives a risk of sediment fluxes alteration in terms, (e.g. in terms of bed load retention)
	Water flow	The method gives a risk of flow regime alteration in terms of barrier structures and water storage (dam, weirs), as well as in terms of drainage network for irrigation. The alteration could interest e.g. flow regime, flow modification, hydropeaking, low flow frequency, etc.
B - LATERAL CONTINUITY	Lateral hydraulic continuity	Through the risk of flow regime alteration in terms of barrier structures (alteration of flood frequency and intensity)
	Sediment (and wood) lateral continuity	It assesses the risk of alteration of soil erosion due to land use at large scale
C - BANK EROSION / STABILITY		It assesses the lack of lateral dynamic because of bank protection structures
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	The method assesses the risk of alteration of channel morphology (lateral and vertical) by the presence of structures such as weirs, channelization, embankments, bank protection, etc. AURAH-CE collects info on vertical incision (qualitative indices, e.g.: erosion at bridge basis, substrate outcropping, etc.)
	Vertical	The method assesses the risk of alteration of channel morphology (lateral and vertical) by the presence of structures such as weirs, channelization, embankments, bank protection, etc. AURAH-CE collects info on vertical bed adjustment (qualitative indices, e.g. erosion at bridge basis, substrate outcropping, etc.)
F - VERTICAL CONTINUITY	Groundwater connection	Water abstraction for irrigation is assessed in terms of risk of alteration of the flow regime
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method has been developed by the Cemagref (now IRSTEA) & Onema since 2006, under the request of the French Ministry of the Ecology and of the Sustainable Development to comply to WFD requirements.
APPLICATION TO ALL WATER BODIES		It has been applied to all the French metropolitan territory
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It can support the definition of several states (such as reference conditions)
USED TO PREDICT RISK OF DETERIORATION		It can be used for this purpose given that it maps/identifies risk zones in terms of sediment fluxes, flow regime and morphology alteration
USED TO IDENTIFY IMPROVEMENT TARGETS		Info collected by the method can be combined with data required for management, programming, decision-making and assessment of restoration actions
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		The method has identified 14 types of hydrological damage which are most likely to be the cause if impact in ecological state of watercourses
KEY STRENGTHS FOR RIVER MANAGEMENT		It is an open/adaptive system and at a national scale It is an open/adaptive system and at a national scale

Appendix E 7 – ROE & ICE (France)

1 - METHOD BACKGROUND			
NAME OR CODE			**ROE & ICE - Référentiel national des Obstacles à l'Ecoulement & Information sur la Continuité Ecologique**
COUNTRY			France
KEY REFERENCE			Onema (2010)
WEBPAGE			http://www.eaufrance.fr/spip.php?rubrique87/
CATEGORY			ROE makes an inventory of available info on longitudinal barriers and homogenizes available data; ICE collects data to assess the longitudinal continuity for fish communities
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	ROE is widely based on cartographic data and maps
		Field survey	ICE protocol is a field survey protocol to collect data on barrier characteristics and general physical channel characters
		Rapid field assessment	NOT APPLICABLE
		Existing database	To build the ROE, the authors first collected data coming from different national and local organizations. The application of the protocol ICE needs to collect bibliographic and existent data on fish species and communities (size, swim velocity, jumping capability, etc.)
		Modelling	Models are used to build decision trees helpful to support the assessment of the barrier passability
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	ROE inventories barriers at national scale; ICE protocol collects data at the local scale (single barrier); data from both systems can be coupled to carry out analysis at several scales (reach, single water body, catchment, region, etc.)
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	NOT APPLICABLE
		Variable length	ROE inventories barriers to longitudinal continuity at the national scale. ICE measures barrier characteristics at single barrier scale and for all the impacted reach length (it depends on barrier type and size)
	LATERAL SPATIAL SCALE	Channel	Both protocols focus only on channel artificial structures; ICE collects some general info on channel morphology
		Banks/Riparian zones	NOT APPLICABLE
		Floodplain	NOT APPLICABLE
C - TEMPORAL SCALE		Physical and morphological assessment	Both protocols focus on present time
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The main aim of ROE is to develop an inventory of longitudinal barriers at the French national scale: info on barriers have been collected and homogenized (identification code, nomenclature and localisation). The ICE protocol serves to get more precise field information and characterize barriers in order to assess the status of the ecological continuity. A part of the protocol concerns fish species and groups of species and their capacity to pass barriers (groups are based on criteria such as size, morphology, jumping ability, similar eco-ethology)
		Assessment by index	Data collected by ICE are used to obtain indices of barrier passability for fish communities (target species or target group of species) and sediments: 4 classes of passability for fishes
		Deviation from reference	NOT APPLICABLE
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	ROE and ICE can be used as a combined protocol. They can be used combined to other French methods (CarHyCE, SYRAH-CE & AURAH-CE) and get an overall evaluation of the hydromorphological status of rivers
E - REFERENCE CONDITIONS			NOT APPLICABLE
F - GENERAL INFORMATION	RIVER TYPOLOGY		NOT APPLICABLE
	TYPOLOGY LIMITATIONS		NOT APPLICABLE
	TYPE-SPECIFIC (Protocol / Assessment method)		The ICE protocol makes a different diagnosis on the basis of the type of barrier

	BASIS FOR STANDARDS / THRESHOLDS		Barrier passability classes (4) are defined on the basis of the level of upstream passability for the species of groups of target species and as function of time (duration of non passability conditions), function of hydrological and thermal conditions during the migration period. Classes are the following: total barrier, partial major barrier, partial significant barrier, low impact barrier. Passability is defined with the support of modelled decision trees (built considering species characteristics and indicators of barrier characteristics)
	REACH SCALE SURVEY STRATEGY		ICE protocol records info on barrier profile (longitudinal and cross section) and physical channel data in the impacted area both upstream and downstream the barrier
	TIMING AND FREQUENCY		ROE needs to be updated regularly. The definitive ICE protocol is under development (at present state it is not a simple, rapid tool)
	DATA PRESENTATION (OUTPUT/LAYOUT)		ROE = an open and integrative database for the national scale and a web application Géobs®
	METHOD SUPPORT / APPLICATION TOOLS		ROE = an open and integrative database for the national scale and a web application Géobs®. ICE = a national standard protocol to collect data on barriers and a guide; an interpretative tool based on bio-physical capacity of fish communities to pass barriers and for sediment; a database on existing data (on fish communities)
	SPATIAL COMPARISON		Data are collected at the national scale, and allow for comparison between rivers in France
	CONNECTION TO ECOLOGY		The connection to ecology is direct, given that the ICE protocol considers barrier passability from the point of view of fish communities
	USERS		Final results (database and web application) can be used by everybody; both tools (ROE and ICE) are useful for management planning as well as for scientists (database of data). The application of the ICE protocol needs some training
	SCALE INFORMATION		Info are collected at the local scale (single barrier) but they can be plotted at the large national scale
	NUMBER OF END PARAMETERS		NOT AVAILABLE
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Large scale characteristics available from cartographic and topographic maps
	HYDROLOGICAL REGIME	Hydrological conditions	ICE records discharge conditions during measurements
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE
	CHANNEL FORMS		NOT APPLICABLE
	BED CONFIGURATION		NOT APPLICABLE
	CHANNEL DIMENSIONS		ICE records channel width (both bankfull and wetted widths), depth and slope, both upstream and downstream the barrier
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		ICE collects info on channel substrate (size) both upstream and downstream the barrier
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Transversal structures (barriers to longitudinal continuity): Weir, small weir, dam, deflector, bridge structures, etc.. The ICE protocol collects feature/structure measured in the field: longitudinal profile, several structural measures (height, material, etc.), filling (for dam, weirs), planform, cross section form, state of conservation, etc. Description of fish pass when present
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		NOT APPLICABLE
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		NOT APPLICABLE
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		NOT APPLICABLE
	LAND USE		NOT APPLICABLE
D -	FLUVIAL FORMS		NOT APPLICABLE

FLOODPLAIN	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	NOT APPLICABLE
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	The aim of the two protocols is to get information on the longitudinal continuity of both sediment and biological communities (fishes)
	Water flow	NOT APPLICABLE
B - LATERAL CONTINUITY	Lateral hydraulic continuity	NOT APPLICABLE (but indirectly assessed)
	Sediment (and wood) lateral continuity	NOT APPLICABLE
C - BANK EROSION / STABILITY		NOT APPLICABLE
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The protocols have been developed because of the need to collect info on the existence, location and characteristics of barriers in an homogenous way with the objective to plan management actions and the final aim to reach the good ecological status
APPLICATION TO ALL WATER BODIES		It applies to all water bodies where artificial longitudinal barriers are present
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		At present, the method is not used for this purpose but it was developed with also the aim to provide a support for the definition of all ecological status
USED TO PREDICT RISK OF DETERIORATION		Results of ICE combined to ROE could be useful for this purpose
USED TO IDENTIFY IMPROVEMENT TARGETS		The ROE database is an integrative tool which should be updated regularly and therefore could be used in monitoring actions. ICE definition of barrier passability is useful to define management actions
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		The link to ecology is direct, therefore it can be used for this purpose (especially for fish communities)
KEY STRENGTHS FOR RIVER MANAGEMENT		The method has wide applicability in water management both at local and national scales (using homogenous data). The ICE protocol is not yet definitive

Appendix E 8 – LAWA-FS (Germany)

1 - METHOD BACKGROUND		
NAME OR CODE		**LAWA-FS - Stream Habitat Survey (Field Survey)**
COUNTRY		Germany
KEY REFERENCE		LAWA (2000, 2002a)
WEBPAGE		
CATEGORY		The method aims to measure the naturalness of a river or stream based on the current hydromorphological features and historical data
2 - METHOD CHARACTERISTICS		
A - SOURCE OF INFORMATION / DATA COLLECTION	Maps/Remote sensing	NOT APPLICABLE
	Field survey	A time consuming, well-structured field method, field survey is done by walking along the river and recording relevant features. 3 ways to record features: dominant feature (e.g. valley form); multiple choice (e.g. flow types); estimation of percentage (e.g. land use)
	Rapid field assessment	NOT APPLICABLE
	Existing database	NOT APPLICABLE
	Modelling	NOT APPLICABLE
B - SPATIAL SCALE – HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method surveys the overall water body but the survey focuses on reach scale. It uses a hierarchical approach at the reach scale: main parameters (6) → functional units → single parameters
B - SPATIAL SCALE – LONGITUDINAL SPATIAL SCALE	Fixed length	100 m is the standard length, but also its multiples are used (depending on channel width), but not exceeding 1 km (for largest rivers)
	Scaled to channel width	NOT APPLICABLE
	Variable length	NOT APPLICABLE
B - SPATIAL SCALE – LATERAL SPATIAL SCALE	Channel	3 main parameters analyzed at channel scale: pattern, longitudinal profile and channel bed features
	Banks/Riparian zones	3 main parameters analyzed at bank scale: cross section and channel bank features (including riparian vegetation); banks are recorded separately
	Floodplain	1 main parameter analyzed at floodplain scale (including also riparian zones): floodplain, assessed within a width of 100 m for each river side
C - TEMPORAL SCALE	Physical and morphological assessment	The method assesses the current state and compare it to a past/reference state
	Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD	Characterization/classification	The method makes a characterization (e.g. presence/absence, extension) of physical river features
	Assessment by index	Mapped features/parameters are scored: a scale of seven points (1 best, 7 worst) is used. Scores are averaged and assigned to 6 main parameters and then averaged to obtain the final score. The method also uses a functional-unit score system, where scores are assigned following a hierarchical approach
	Deviation from reference	The method assesses the status of the river in comparison to the potential reference conditions
	General assessment / Design framework	NOT APPLICABLE
	Modelling status / Scenario	NOT APPLICABLE
	Final expert judgment	There is an ‘expert opinion’ entry, which acts as quality assurance: deviations between the computed scores from the individual attributes and expert opinion are cross-checked (Raven et al., 2002)
	Links with other systems	It could be used in conjunction to the Overview survey to get large spatial scale information
E - REFERENCE CONDITIONS		Reference conditions ('Leitbild') are defined empirically or modelled, and correspond to the potentially state to which the stream would develop without further human influence
F - GENERAL INFORMATION	RIVER TYPOLOGY	Germany uses system A to define river typologies: 24 river typologies are identified, but the method only differentiates between six major geomorphologically based river types with valley shape and slope as relevant factors
	TYPOLOGY LIMITATIONS	The method is not adapted to be applied to large rivers, braided reaches, and seasonal watercourses

	TYPE-SPECIFIC (Protocol / Assessment method)		The method was initially developed for small to medium sized streams, but later extended to large rivers: two distinct and specific field survey protocols exist for "small to medium" and for "medium to large" rivers. The method uses a type-specific score system for the main parameters
	BASIS FOR STANDARDS / THRESHOLDS		All parameters have similar ecological potential (no weighting), but 6 main parameters are scored differently in relation to stream type. Evaluation is computed and checked by calibration against a natural or near-natural river reach (reference). 7 classes are used: 1=Unchanged, 2=Slightly changed, 3=Moderately changed, 4=Distinctly changed, 5=Obviously changed, 6=Strongly changed, 7=Completely changed
	REACH SCALE SURVEY STRATEGY		No reach scale survey strategy, features are recorded by walking along the stream/river; all the river has to be assessed in continuum
	TIMING AND FREQUENCY		The field survey method is time consuming; the recommended monitoring frequency is 6 years, with respect to morphology and continuity (Weiss et al., 2008)
	DATA PRESENTATION (OUTPUT/LAYOUT)		Final index, colour-coded maps and entered in a GIS server
	METHOD SUPPORT / APPLICATION TOOLS		A manual; paper or palm pilot protocols; identification sheet (to record general characteristics)
	SPATIAL COMPARISON		Comparison between water bodies is possible and to some extend used to determine the 'naturalness' of the water body
	CONNECTION TO ECOLOGY		It links hydromorphological features to the ecological functioning of the channel and floodplain; It is able to detect local variations in features contributing to habitat character (because of small reach scale approach)
	USERS		Resulting maps present and interpret the survey results in a manner understandable by non-expert users and a wide range of stakeholders
	SCALE INFORMATION		Only reach scale information is processed (large scale info collected to determine river type and reference conditions)
	NUMBER OF END PARAMETERS		6 main parameters/indicators for both protocols: 29 end parameters for small to medium size rivers and 31 end parameters for medium to large size rivers (organised into 14 functional units)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	Flow diversity
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		River valley type
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Constrained, sinuate, meandering, anastomosing (the last recorded as specific structures/features indicators of channel dynamics)
	CHANNEL FORMS		Side bars, point bars or mid-channel bars; islands are recorded as specific structures/features (indicators of channel dynamics)
	BED CONFIGURATION		Indicated as special bed features (into "Channel bed features/morphology")
	CHANNEL DIMENSIONS		Depth diversity; banktop height; diversity in channel width
	FLOW-TYPE		Flow types are assessed
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Dominant substrate (mud, sand, gravel, stones, bedrock); substrate diversity
	IN-CHANNEL VEGETATION		Recoded as "Channel bed features/morphology"
	WOODY DEBRIS		Fallen trees, debris dams (assessed as special features of "Channel pattern"); woody debris are recorded also along the banks
	ARTIFICIAL FEATURES AND STRUCTURES		Some features indicated under the main parameter "Longitudinal profile" (artificial structures, culverting, impoundment); other under "Channel bed features/morphology" (bed fixation/modifications); pollution effect (erosion, sewage)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Cross section form (e.g. natural, near natural, different artificial stages) and depth
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Woody and herbaceous vegetation
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	Special features at banks (e.g. side channel around a tree, fallen tree parallel to bank, woody debris)
	ARTIFICIAL FEATURES AND STRUCTURES	Bank fixation/modification (e.g. concrete, gabion, stones, etc.); obvious pollution effects (sewage, litter, sewage overflows, poaching)
	LAND USE	Riparian buffer strip (native deciduous forest, coniferous forest, grassland, urban area, agricultural use, typical standing water bodies), recorded as floodplain parameter
D - FLOODPLAIN	FLUVIAL FORMS	Special floodplain features/structures (backwaters, side arms, oxbows, springs, natural lakes, natural terraces, etc.)
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	Land use (native deciduous forest, coniferous forest, grassland, urban area, agricultural use, typical standing water bodies); infrastructure works / impacts (e.g. fishpond, roads, impoundments, dumps, purification plants, etc.)
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood Water flow	Presence of natural and anthropogenic migration barriers
B - LATERAL CONTINUITY	Lateral hydraulic continuity	Assessed through the mapping of artificial features
	Sediment (and wood) lateral continuity	NOT APPLICABLE
C - BANK EROSION / STABILITY		Erosion of bend (assessed as parameter of "Channel pattern"); bank erosion
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		It represents the most commonly used method in Germany for the implementation of the WFD (most of the 16 federal states), but not (yet) the formally selected method; it is possible to convert the 7 quality classes into 5 required by WFD
APPLICATION TO ALL WATER BODIES		It applies to all river types identified in Germany comparable to the water quality
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It could be used in the classification of any river status
USED TO PREDICT RISK OF DETERIORATION		Potentially able to detect risk of deterioration
USED TO IDENTIFY IMPROVEMENT TARGETS		It could be used for local to regional river maintenance plans and river development plans; the method also aims to assess the impact of river engineering or rehabilitation
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		The method is type-specific and refers to a specific/potential reference state, and the classification systems with 7 classes is comparable to the hydro-biological and physical-chemical features commonly used in Germany
KEY STRENGTHS FOR RIVER MANAGEMENT		It is able to distinguish local variations in features contributing to habitat character (because of small reach-scale approach); features are surveyed in continuum

Appendix E 9 –LAWA-OS (Germany)

1 - METHOD BACKGROUND			
NAME OR CODE			**LAWA-OS - Overview Survey**
COUNTRY			Germany
KEY REFERENCE			LAWA (2002b)
WEBPAGE			
CATEGORY			The aim is to get an overview of the physical/hydromorphological conditions of rivers
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Present and historical maps (topographic, geological, land use, etc.), aerial, satellite photos and other GIS tools are used for the Overview survey
		Field survey	NOT APPLICABLE (but a ground check is recommended)
		Rapid field assessment	NOT APPLICABLE
		Existing database	Flood statistics, reports, plans, etc.
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Consistent with LAWA-FS but 2 main parameters (instead of 6)
	LONGITUDINAL SPATIAL SCALE	Fixed length	The river is divided into reach 500m-1km long
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Included and assessed as riverbed dynamics
		Banks/Riparian zones	Included and assessed as riverbed dynamics
		Floodplain	Included and assessed as floodplain dynamics (all the floodplain is considered)
C - TEMPORAL SCALE		Physical and morphological assessment	Same as LAWA-FS
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method makes an inventorying and maps features
		Assessment by index	The method mainly uses a functional-unit score system, where scores are assigned following a the hierarchical/stepwise approach
		Deviation from reference	Same as LAWA-FS
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	Local expert knowledge provides information on the possibility of water flow across the floodplain and on artificial barriers (Weiss et al., 2008)
		Links with other systems	In conjunction to LAWA-FS to get more detailed observations; it could also be used when field conditions are not favourable to apply LAWA-FS
E - REFERENCE CONDITIONS			Same as LAWA-FS
F - GENERAL INFORMATION	RIVER TYPOLOGY		Same as LAWA-FS
	TYPOLOGY LIMITATIONS		Consistent with LAWA-FS (except for large rivers); it depends upon data availability; not applicable to small rivers
	TYPE-SPECIFIC (Protocol / Assessment method)		It applies to large rivers more than 10 m wide (where features are visible form maps)
	BASIS FOR STANDARDS / THRESHOLDS		The individual parameters are associated stepwise because of different ecological value. The total value of 'hydromorphological quality' results from the combination of the two partial values 'river-bed dynamics' and 'floodplain'. Same score classes as for LAWA-FS
	REACH SCALE SURVEY STRATEGY		No particular reach survey strategy, all the river is assessed in continuum (more attention at the lateral spatial scale --> floodplain)
	TIMING AND FREQUENCY		The overview survey is less time consuming than the field survey method; the recommended monitoring frequency is 6 years, with respect to morphology and continuity (Weiss et al., 2008)
	DATA PRESENTATION (OUTPUT/LAYOUT)		Same as LAWA-FS
	METHOD SUPPORT / APPLICATION TOOLS		A standardized survey sheet for each 500 m-1 km survey; surveys cross-checked by two or more surveyors
	SPATIAL COMPARISON		Consistent with LAWA-FS (but for large rivers)
	CONNECTION TO ECOLOGY		The scoring system weights in parameters following their ecological relevance, but direct connections between habitat and biology are difficult because of the large-scale approach
	USERS		Same as LAWA-FS

	SCALE INFORMATION		Large scale characteristics are collected and used as basis for the reach scale assessment
	NUMBER OF END PARAMETERS		2 main parameters/indicators divided into 17 parameters (organised into 3 functional units)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Large scale land use, info on water regulation
	HYDROLOGICAL REGIME	Hydrological conditions	Discharge regulation
		Metrics of hydrological regime	Flood frequency
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		River valley type
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Curvature, river planform
	CHANNEL FORMS		NOT AVAILABLE
	BED CONFIGURATION		NOT AVAILABLE
	CHANNEL DIMENSIONS		Variation in width
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		NOT APPLICABLE
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		E.g. Weirs
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		NOT APPLICABLE
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		NOT APPLICABLE
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Existence of bank vegetation; River belt mapping
	ARTIFICIAL FEATURES AND STRUCTURES		Bank protection
	LAND USE		Land use in the riparian belt
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Land use in the floodplain
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Migration barriers
		Water flow	Migration barriers
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Flood protection measures
		Sediment (and wood) lateral continuity	Potential for river-bed migration
C - BANK EROSION / STABILITY			Bank erosion, stability of the profile
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			It has been accepted by Germany in the first ''River Basin District Analysis 2004'' (DE: Bestandsaufnahme 2004) (Weiss et al., 2008), but it lacks some information required by WFD (because of no field survey)
APPLICATION TO ALL WATER BODIES			It applies to large rivers when data are available
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			Consistent with LAWA-FS but less powerful because less information collected
USED TO PREDICT RISK OF DETERIORATION			
USED TO IDENTIFY IMPROVEMENT TARGETS			
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			
KEY STRENGTHS FOR RIVER MANAGEMENT			It uses a fast and not much expensive approach (possible to produce regional and nation-wide surveys); features are carried out continuously

Appendix E 10 – RHAT (Northern Ireland & Republic of Ireland)

1 - METHOD BACKGROUND			
NAME OR CODE			**RHAT - River Hydromorphology Assessment Technique**
COUNTRY			Northern Ireland & Republic of Ireland
KEY REFERENCE			Murphy & Toland (2012)
WEBPAGE			
CATEGORY			The method mostly characterizes physical habitats even though the intent is to give a holistic visual assessment
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	A preliminary "Desk-study" is conducted prior to field work (historical maps for historical changes in planform/pattern, vegetation cover types, general river width, info on artificial pressures, preliminary assessment/identification of bank vegetation, etc.)
		Field survey	Spot-check survey (one 10 m stretch): to assess pressures/specific characters situated not in the selected reach (to better assess the river body as a whole); when there are limitations to carry out a full RHAT field survey (in that case data are collected from a vantage point, such as a bridge). Full RHAT survey: along all the river reach by stopping each 50 m (stretches) + sweep-up survey
		Rapid field assessment	NOT APPLICABLE
		Existing database	Information on restoration or management activity
		Modelling	It uses COMPASS Typology prediction tool, to predict river typology from characters such as sinuosity, etc. (during the Desk-study). Typology must be confirmed in the field
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Information is collected at the catchment scale but only the reach scale is assessed
	LONGITUDINAL SPATIAL SCALE	Fixed length	Stretch (& single Spot-check) = 50 m field survey; Sweep-up field observations = 500 m, a full RHAT survey = 10 stretches each 50 m + Sweep-up
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Assessed at 10 stretches of 50 m each one, and at the Sweep-up scale (500 m)
		Banks/Riparian zones	Assessed at 10 stretches of 50 m each one, and within 1 m, between 1 and 5 m and between 5 and 20 m from the banktop, and at the Sweep-up scale (500 m)
		Floodplain	
C - TEMPORAL SCALE		Physical and morphological assessment	The method assesses mainly the present time, but information on channel changes (pattern, adjustments, etc.) is collected during the Desk-study phase
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The method makes a qualitative (sometimes semi-quantitative) inventory presence/absence/excessive presence) and characterization of features
		Assessment by index	The method carries out a classification of hydromorphological status according to 8 criteria: 1.Channel morphology and flow types; 2. Channel vegetation; 3. Substrate diversity and condition; 4. Barriers to continuity; 5. Bank structure and stability; 6. Bank and bank top vegetation; 7. Riparian land cover; 8. Floodplain interaction. 8 classified attributes are scored from 4 (high) to 0 (bad) => Hydromorph Score = sum of attribute scores/32 (from 0 to 1)
		Deviation from reference	It classifies river hymo based on the deviation from naturalness (depending on river type)
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	NIEA developed a method to convert RHS survey into RHAT classification using field forms, photographs and maps (Webster et al. (2011), to allow the comparison between recent RHAT surveys and previous RHS surveys
E - REFERENCE CONDITIONS			The method uses a theoretical approach of reference conditions based on expected (modelled) river type; the scoring system provides a description of each reference river types for each of the 8 assessment categories
F - GENERAL INFORMATION	RIVER TYPOLOGY		Four RHAT river types: bedrock (BED), step-pool-cascade (CSP), pool-riffle-glide (PRG) and lowland meandering (LLM). These are defined on the basis of selected features (system A)

	TYPOLOGY LIMITATIONS		The use of RHAT method is limited to selected river typologies. It does not apply to ephemeral streams and to multi-thread rivers
	TYPE-SPECIFIC (Protocol / Assessment method)		No type specific protocol or assessment method for river types (but river types are considered when attributes are scored/assessed)
	BASIS FOR STANDARDS / THRESHOLDS		A description of deviation from high status is provided in the scoring system for each status class: high = 95-100% natural; good = 85-95% natural; moderate = 65-85% natural; poor = 25-65% natural; bad < 25% natural
	REACH SCALE SURVEY STRATEGY		A reach is selected as representative of the water body: 10 stretch each 50 meters + sweep-up (overview) survey. 2 additional Spot-check are assessed to validate the river status classification
	TIMING AND FREQUENCY		No information on duration is available. For intercalibration and quality control purposes, two sites per surveyor (per survey season May-September) should be surveyed
	DATA PRESENTATION (OUTPUT/LAYOUT)		Field forms, classification status, photos, Hydromorph Score (index)
	METHOD SUPPORT / APPLICATION TOOLS		A manual with Field sheets and Guidance notes is provided, as well as a Scoring System manual. It is also recommended to take photos which will help to record and assess features satisfactorily; a photo detail sheet is provided
	SPATIAL COMPARISON		It may be possible between same river types
	CONNECTION TO ECOLOGY		It could be used to assess eco-relevant habitat changes, given that it records the presence of shading, fallen trees, leafy debris, etc., and it evaluates the diversity and quality of in-channel habitats (attribute 2) and bank/riparian habitats (attribute 6)
	USERS		It is recommended to follow a specific training from RHAT accredited by NIEA/EPA staff (attribution of a surveyor code)
	SCALE INFORMATION		Both large and local scale info are collected to characterize a water body (not catchment scale)
	NUMBER OF END PARAMETERS		4 sheets: Sheet 1 = Site identification info, Desk-study notes and Field notes; Sheet 2 = scoring system (8 attributes assessed); Sheet 3 and 4 = field observations at 10 stretches (3) and Sweep-up (4). Parameters observed (in the field): 5 main and 38 sub-parameters (sheet 3) + 7 main and 26 sub-parameters (sheet 4)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Geology, vegetation cover types, land cover, large scale pressures
	HYDROLOGICAL REGIME	Hydrological conditions	It also records the weather during the weeks before the survey (if rainy)
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		7 types of river valley form to be assessed on the field
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Straightening, widening changes from map/photo analysis
	CHANNEL FORMS		Channel forms are partially recorded at the "Bank and Channel Features" section at Sweep-up scale
	BED CONFIGURATION		Their presence/absence is evaluated at the specific river type
	CHANNEL DIMENSIONS		River width estimated on the Desk study and on the field at three places within the first 50 m, to the nearest meter; river depth is also estimated at the start of the survey
	FLOW-TYPE		Same as RHS
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Same as RHS
	IN-CHANNEL VEGETATION		Marginal emergent plants, Liverworts/mosses/lichens and In-Channel vegetation (several categories)
	WOODY DEBRIS		Called "Woody habitat", includes tree trunks, logs, twigs and branches
	ARTIFICIAL FEATURES AND STRUCTURES		Named "Channel modifications", same as RHS. It also counts the number of bridges and weirs, proportionally to their physical (spatial) impact on stretch. Channel modifications are assessed either at the Stretch (detailed) and the Sweep-up scale of analysis (for the extension)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Indirectly assessed through "eroding/stable cliff
	BANK MATERIAL		Same as RHS
	RIPARIAN VEGETATION STRUCTURE		Same as RHS (at banktop and bankface)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Same as RHS; assessed at the Sweep-up scale
	RIPARIAN VEGETATION WIDTH		Probably indirectly assessed through riparian land cover types

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	The presence and qualitative extension of bank non-native/disturbance species
	ARTIFICIAL FEATURES AND STRUCTURES	"Bank modifications" same as RHS. Bank modifications are assessed both at the Stretch (detailed) and the Sweep-up scale of analysis (for the extension)
	LAND USE	Land use and land cover within 1 m, between 1 and 5 m and between 5 and 20 m from the banktop. Riparian land cover status is assessed with attribute 7
D - FLOODPLAIN	FLUVIAL FORMS	Same as RHS. They are recorded at the "Bank and Channel Features" under "other natural features" section at Sweep-up scale
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	Land use and land cover within 1 m, between 1 and 5 m and between 5 and 20 m from the banktop; Type of resource uses that take place around the river
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	The method assesses the impact of Barriers to continuity (attribute 4) from a large point of view
	Water flow	The method assesses the impact of Barriers to continuity (attribute 4) from a large point of view
B - LATERAL CONTINUITY	Lateral hydraulic continuity	The method records whether the channel is naturally or artificially confined, or not confined, and it uses this information for the score of Floodplain interaction (attribute 8)
	Sediment (and wood) lateral continuity	The method assesses sediment diversity and conditions (attribute 3), specifically for each river types; in relation to upstream network contribution (mainly from tributary)
C - BANK EROSION / STABILITY		Bank erosion/stability is assessed in terms of deviation from natural expected dynamic for each river type (attribute 5)
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	The method uses historical maps/photos during the Desk-study phase to highlight and support the assessment of historical changes in planform/pattern (attribute 1)
	Vertical	NOT APPLICABLE (it is considered only in terms of floodplain connection, attribute 8)
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method has been developed from the RAT (Richards, 1996) previously developed on the basis of RHS and US-RBP. It complies with CEN standard and WFD requirements. RHAT has been developed specifically for Water Framework Directive compliance
APPLICATION TO ALL WATER BODIES		Consistently with WFD, the method records resource uses that take place around the river (so potentially used for the designation of HMWBs and AWBs)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		Used in the classification of any status: a minimum of one full RHAT survey and 2 spot checks (to confirm or reject the results of RHAT survey) are required to water body classification using RHAT
USED TO PREDICT RISK OF DETERIORATION		Potentially able to detect risk of deterioration
USED TO IDENTIFY IMPROVEMENT TARGETS		It could be used in deciding what indirect and direct efforts are needed to improve status
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		Following the authors, RHAT plays a vital role in identifying why a water body might be failing to achieve good ecological status
KEY STRENGTHS FOR RIVER MANAGEMENT		Easiness of application, cost-effective, flexible in the field (e.g. the score is adjusted when a feature is not visible on the field), it provides results closely aligned to expert-based assessments (at least in Irish rivers)

Appendix E 11 – CARAVAGGIO (Italy)

1 - METHOD BACKGROUND

NAME OR CODE	**CARAVAGGIO - Core assessment of river habitat value and hydro-morphological conditions**
COUNTRY	Italy
KEY REFERENCE	Buffagni et al. (2005)
WEBPAGE	
CATEGORY	The method has been developed to adapt RHS to the Italian context and , more in general, to Mediterranean rivers. It focuses on the characterization and assessment of physical habitat and the overall hydromorphological state

2 - METHOD CHARACTERISTICS

A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	The method collects some map-based general characteristics
		Field survey	Consistent with RHS. It collects some additional features specific of Mediterranean rivers
		Rapid field assessment	NOT APPLICABLE
		Existing database	Same as RHS
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Same as RHS
	LONGITUDINAL SPATIAL SCALE	Fixed length	Same as RHS
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Consistent with RHS. Natural and artificial channel characteristics (both for main and secondary channel) are recorded on a map for all the 500 m of reach length
		Banks/Riparian zones	Consistent with RHS. Banks are assessed separately from the channel
		Floodplain	Consistent with RHS
C - TEMPORAL SCALE		Physical and morphological assessment	Same as RHS
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	Consistent with RHS; it collects some additional river features compared to RHS (e.g. characterization of secondary channels, indication about secondary flow types and substrate)
		Assessment by index	4 descriptors: HQA (habitat quality assessment), HMS (Habitat Modification score), LUI (Land Use Index), LRD (Lentic-lotic River Descriptor). First 3 indices are used to calculate IQH (Habitat Quality Index): they are converted into EQR and averaged to obtain the final index
		Deviation from reference	The quality assessment is compared to reference site conditions
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	HMS and HQA are the same as RHS; other indices thresholds are defined by the expert judgment of the authors, on the basis of data collected on reference sites
		Links with other systems	The IQH is a multiple index (HQA + HMS + LUI)
E - REFERENCE CONDITIONS			It uses a theoretical definition of reference sites, identified as those in which the human impact is absent. The results of the CARAVAGGIO method can support/validate the definition of reference sites
F - GENERAL INFORMATION	RIVER TYPOLOGY		It uses a river typology combining system A and B of the WFD
	TYPOLOGY LIMITATIONS		It applies to Mediterranean rivers
	TYPE-SPECIFIC (Protocol / Assessment method)		NOT APPLICABLE
	BASIS FOR STANDARDS / THRESHOLDS		For HQA and HMS, same as RHS. For LUI: 5 score-classes following the land use (0=natural to 5=urban). For LRD: it gives positive scores to lotic characteristics and negative to lotic ones, at the same time considering natural characteristics (LRDn) and artificial modifications (LRDa); the sub-indices are summed to give the LRDtot
	REACH SCALE SURVEY STRATEGY		Same as RHS
	TIMING AND FREQUENCY		Same as RHS
	DATA PRESENTATION (OUTPUT/LAYOUT)		Several final indices; a database

	METHOD SUPPORT / APPLICATION TOOLS		A standard protocol to collect field data (4 pages), some explicative papers and a Software (Caravaggiosoft) for data collection and processing
	SPATIAL COMPARISON		Consistent with RHS
	CONNECTION TO ECOLOGY		Consistent with RHS. Additionally, the LRD has specifically been developed to help in the characterization of habitats for macroinvertebrates
	USERS		Same as RHS
	SCALE INFORMATION		Same as RHS
	NUMBER OF END PARAMETERS		92 parameters (+ sub-parameters, with some of them collected for different morphological units: i.e. for both banks, for main/secondary channel, for channel/banks/banktop), organised in 17 main sections
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Valley characteristics and general channel morphology
	HYDROLOGICAL REGIME	Hydrological conditions	Differently from RHS, it also considers the lentic-lotic character of rivers (being important in Mediterranean rivers); it comes from data collected at spot-checks (flow type, depth, substrate, organic matter and debris) and sweep-up (flow type and depositional features)
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	It assesses if the river is subject to hydropeaking
	VALLEY FORM / FEATURES		Consistent with RHS. Info could be obtained from existing maps
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Channel morphology (e.g. sinuous, meandering, braided) and general conditions of the reach (naturally/artificially confined). Info could be obtained from existing maps
	CHANNEL FORMS		It records the presence and number of selected channel form features (transverse/alternate/concave bar, vegetated/unvegetated point/lateral bar, mature island, etc.). At the overall reach scale it also records some main bar forms (lobated)
	BED CONFIGURATION		It records the number of selected bed configuration features (riffle, pool, nickpoint, eroded alluvial deposits, etc.)
	CHANNEL DIMENSIONS		Either for main and secondary channel: position of wetted channel; wetted channel width; maximum depth; Total wetted and total channel width
	FLOW-TYPE		Consistent with RHS. Flow types recorded either for main and secondary channel; it also records the main and secondary flow types
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Coherent to RHS. Substrate type recorded both for main and secondary channel; it records both the main and secondary substrate type. It records, at the overall reach scale, the presence of fine sediments in pools and large sediments in riffle
	IN-CHANNEL VEGETATION		Consistent with RHS
	WOODY DEBRIS		Consistent with RHS
	ARTIFICIAL FEATURES AND STRUCTURES		Consistent with RHS but either for main and secondary channel. It records also the position of artificial features along the 500 m reach on a map
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Consistent with RHS. It also measures bank extent and bank slope
	BANK MATERIAL		Consistent with RHS
	RIPARIAN VEGETATION STRUCTURE		Consistent with RHS
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Consistent with RHS
	RIPARIAN VEGETATION WIDTH		It measures riparian vegetation width
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Consistent with RHS. It also records the riparian tree vegetation composition (presence/absence/extension) on bank and banktop and also channel (islands, bars), both for natural and exotic species
	ARTIFICIAL FEATURES AND STRUCTURES		Consistent with RHS
	LAND USE		Land use at 5m on banktop (spot-check) is used to calculate the LUI, together with the land use at 50m on banktop (sweep-up)
D - FLOODPLAIN	FLUVIAL FORMS		Coherent to RHS
	INFO ON FLOODPLAIN FEATURES		It records the presence of large boulder in the floodplain as well as glacial deposits (at the overall reach scale, as special features)

LAND USE		Land use at 50 m on banktop (sweep-up) is used to calculate the LUI, together with the land use at 5 m on banktop (spot-check). At the overall reach scale it records also if agriculture field are tilled parallel or orthogonally to the river flow direction
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	Consistent with RHS
	Water flow	Consistent with RHS. The presence of hydropeaking is also noted
B - LATERAL CONTINUITY	Lateral hydraulic continuity	Consistent with RHS
	Sediment (and wood) lateral continuity	Consistent with RHS
C - BANK EROSION / STABILITY		Consistent with RHS
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	It records tracks of evident river incision
F - VERTICAL CONTINUITY	Groundwater connection	Consistent with
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		It has been developed as compulsory method only for reference sites
APPLICATION TO ALL WATER BODIES		It applies to all river bodies at least in Italy and Mediterranean rivers
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It has been used to help in the definition of Italian reference sites. The IQH is used to define high ecological status (only 2 classes)
USED TO PREDICT RISK OF DETERIORATION		It can be potentially used to define the risk of deterioration of physical habitats
USED TO IDENTIFY IMPROVEMENT TARGETS		Consistent with RHS
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		Consistent with RHS
KEY STRENGTHS FOR RIVER MANAGEMENT		It can be used characterize/inventory in detail physical habitats and to get an overall state of physical structure of rivers

Appendix E 12 – MQI (Italy)

1 - METHOD BACKGROUND			
NAME OR CODE			**MQI - Morphological Quality Index**
COUNTRY			Italy
KEY REFERENCE			Rinaldi et al. (2013)
WEBPAGE			
CATEGORY			The method aims to assess the morphological quality of rivers based on river geomorphic forms and processes
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Maps (e.g. topographic, geological, geomorphological), and remote sensing data (e.g. aerial images, DEM) are used in the first part of segmentation of the river network, in the historical analysis (Channel Changes), as well as most of the features in the evaluation form
		Field survey	Field survey is accomplished at one or more representative sub-reaches (‘sites’)
		Rapid field assessment	NOT APPLICABLE
		Existing database	Inventory of artificial intervention (if existing), information on river management/practices (e.g. sediment / wood removal) from public agencies
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method adopts a hierarchical nested approach where the reach represents the basic spatial unit of assessment
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	NOT APPLICABLE
		Variable length	The method uses the concept of homogenous reaches, where present morphological conditions are sufficiently uniform; their identification is carried out during the initial phase of river segmentation
	LATERAL SPATIAL SCALE	Channel	All the channel bed is assessed
		Banks/Riparian zones	Bank and riparian zones are included in the assessment
		Floodplain	Floodplain (and terraces) is included in the assessment
C - TEMPORAL SCALE		Physical and morphological assessment	Present conditions are assessed; historical analysis of channel adjustments (last 50 – 100 years) is performed
		Hydrological assessment	Alteration of channel-forming discharges and/or flows with higher return period are evaluated
D - TYPE OF METHOD		Characterization/classification	The method makes an initial classification/segmentation of river reaches relevant for the assessment procedure (4 steps: Physiographic units, Confinement, River Morphology, Longitudinal discontinuities)
		Assessment by index	The IAM (Morphology Alteration Index) and the MQI (Morphology Quality Index) are calculated as result of the evaluation form; IAM = Stot/Smax (score tot/maximum score of alteration); MQI = 1-IAM (from 0 to 1)
		Deviation from reference	The method measures the deviation from undisturbed or only very slightly disturbed geomorphic conditions
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	The expert judgment of the authors was used several times in the method protocol and definition (selection of variables, indicators, classes, and scores)
		Links with other systems	The method is part of the methodology IDRAIM (system for stream hydromorphological assessment, analysis, and monitoring) which aims to an integrated analysis of morphological quality and channel dynamics hazard
E - REFERENCE CONDITIONS			Theoretical reference conditions are defined (by expert judgement of authors) as: (a) full functionality of geomorphic processes; (b) absence or negligible presence of artificial elements along the reach and to some extent in the catchment; (c) absence of significant adjustments due to channel instability (configuration, width, bed elevation) over a temporal frame of about 100 years
F - GENERAL INFORMATION	RIVER TYPOLOGY		River reaches are defined on the basis of a hierarchical classification process which considers mainly physical characters: physiographic units, confinement, river morphology, and other river discontinuities
	TYPOLOGY LIMITATIONS		The method potentially applies to all stream types (but verification over EU and non-EU country is recommended)

	TYPE-SPECIFIC (Protocol / Assessment method)		The method provides two different evaluation protocols for confined and partly confined/unconfined channels
	BASIS FOR STANDARDS / THRESHOLDS		Thresholds, as well as reference conditions, are defined by expert judgment of the authors. For each indicators, in most cases, 3 classes are used: class A = reference conditions (value = 0 = no alteration), class B = intermediate conditions (variable scores); class C = completely altered conditions (variable scores depending on the importance assigned to each indicators, generally 5 or 6). A degree of confidence and a second choice can be also assigned to each indicator (and used to define a range of final MQI value). MQI classes: high, MQI>0.85; good, MQI=0.7÷0.85; moderate, MQI= 0.5÷0.7; poor, MQI=0.3÷0.5; bad, MQI=0÷0.3
	REACH SCALE SURVEY STRATEGY		The reach represents the basic spatial unit, maps and remote sensing are used for the reach scale assessment; field survey is carried out along a representative sub-reach
	TIMING AND FREQUENCY		Authors indicate that the duration of the survey depends upon the background of the surveyor. Frequency: not indicated, but for WFD monitoring every 3-6 years
	DATA PRESENTATION (OUTPUT/LAYOUT)		Field forms; classification in quality classes (several outputs); 2 main indices (quality and alteration) and several sub-indices (vertical, horizontal sub-indices)
	METHOD SUPPORT / APPLICATION TOOLS		A guidebook is provided (with field forms and guidance for compilation)
	SPATIAL COMPARISON		The method could be used to make comparison at least among Italian rivers. It could potentially be used in other EU and non-EU countries but verifications/calibrations are needed to check whether the method covers the full range of physical conditions and morphological types
	CONNECTION TO ECOLOGY		NOT APPLICABLE (but indirectly some information is provided through the assessment of large wood, substrate alterations, etc.)
	USERS		Environmental or water agencies, managers, scientists, with training and adequate background (fluvial geomorphology)
	SCALE INFORMATION		The method uses a hierarchical nested approach; it gives information at large (river type classification) and reach (status classification) scales
	NUMBER OF END PARAMETERS		The method assesses 28 indicators divided into 3 main components: F, functionality (13 indicators); A, artificiality (12 indicators); V, channel changes (3 indicators)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Large scale characteristics are investigated at Steps 1 and 2 of the initial segmentation phase: geology, geomorphology, climate and land use
	HYDROLOGICAL REGIME	Hydrological conditions	The method takes into account only hydrological aspects which have influence on morphological processes => alterations of channel-forming discharges
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		Valley slope is considered; valley form partially assessed in term of confinement
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Channel pattern and planform characters are used in the Step 3 of the initial segmentation (definition of river morphology)
	CHANNEL FORMS		Following the reach pattern type, the presence of expected forms is assessed
	BED CONFIGURATION		Bed configuration is assessed for a further classification of river morphology in steep, confined rivers (but it does not affect river segmentation). Bed configuration is also used in one indicator for confined streams
	CHANNEL DIMENSIONS		Channel width is required and is take into account in the assessment of some indicators
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		The alteration of channel bed is assessed (e.g. armouring, clogging, bedrock outcropping bed revetments)
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		The presence of in-channel large woods is assessed as well as wood removal practices

	ARTIFICIAL FEATURES AND STRUCTURES		Many types of artificial features and structures are considered in the assessment of artificiality, including alteration of discharge (spillway, diversions, retention catchments), as well as alteration of sediment transport (check dams, weirs, diversion structures, etc.). The presence and frequency of crossing structures which interfere with the fluvial corridor is also assessed (bridges, fords, culverts)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Bank profile/shape is assessed in terms of expected variability of the cross section for the river reach type
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		The riparian vegetation structure is assessed within the evaluation of the width of functional vegetation
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		The linear extension of functional vegetation along the banks is assessed
	RIPARIAN VEGETATION WIDTH		The width of functional vegetation is assessed in relation to its natural expected presence
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Presence, position and longitudinal continuity of banks protections and artificial levees is assessed
	LAND USE		Land use on the banks and riparian zone is indirectly assessed by the indicators of riparian vegetation (e.g. presence and width of functional riparian vegetation, management of riparian vegetation)
D - FLOODPLAIN	FLUVIAL FORMS		In lowland, low energy river reaches, the presence of expected landforms in the floodplain (oxbow lakes, secondary channels, etc.) is assessed
	INFO ON FLOODPLAIN FEATURES		The presence and extension of a 'modern' floodplain is assessed; the width of the whole floodplain (modern floodplain and recent terraces) is considered in the degree of confinement and in the evaluation of the potentially erodible corridor
	LAND USE		Floodplain land use is indirectly assessed by the indicators of riparian vegetation
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Longitudinal continuity in sediment and wood flux are indirectly assessed based on the presence of transversal structures, as well as the upstream alteration of sediment discharges
		Water flow	The longitudinal continuity alteration of channel-forming discharge is assessed both at reach and larger scales
B - LATERAL CONTINUITY		Lateral hydraulic continuity	The lateral hydraulic continuity is assessed through the presence of a 'modern' floodplain
		Sediment (and wood) lateral continuity	The lateral continuity of sediment ad fluxes is assessed through the presence of a 'modern' floodplain, the potentially erodible corridor and, for confined channels, through the connectivity between the river corridor and its hillslopes
C - BANK EROSION / STABILITY			Processes of bank retreat are assessed as important for sediment supply and recovery
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	Historical changes in channel pattern are evaluated, as well as historical changes in channel width. Artificial changes of channel courses are also evaluated (meander cut-off, channel diversions, etc.)
		Vertical	Data from topographic surveys (cross-section and longitudinal profiles, past and present) are used to assess vertical adjustments, given their importance in several river processes (floodplain connectivity, in-channel habitats, etc.)
F - VERTICAL CONTINUITY		Groundwater connection	The presence of bed-revetments, which alter the vertical continuity, is assessed
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method has been designed to comply with WFD requirements; it has been formally approved for application (at least) to all water bodies in high state. It could be used for other purposes in river management
APPLICATION TO ALL WATER BODIES			It is also applied for the designation of HMWBs (in progress)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			It could be used in the classification of any status
USED TO PREDICT RISK OF DETERIORATION			It can be used to predict risk of deterioration since it assesses past and present human impacts and separates artificiality from functionality and instability
USED TO IDENTIFY IMPROVEMENT TARGETS			It can be used to identify improvement targets, starting from the assessment of the quality and the alteration states and

	because it separates artificiality from functionality
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS	If properly linked to ecological data it can be used to identify ecological impacts, given that it makes a detailed analysis of impact (artificiality)
KEY STRENGTHS FOR RIVER MANAGEMENT	The method has been developed to be used by environmental or water agencies on a national level; it evaluates processes and takes into account the temporal context/changes; the protocol aims to an assessment of morphological conditions rather than a features inventorying. It defines different protocols for lowland unconfined and confined rivers

Appendix E 13 – Methodology for the assessment of hydromorphological changes (Latvia)

1 - METHOD BACKGROUND			
NAME OR CODE			**Methodology for the assessment of Hydromorphological changes**
COUNTRY			Latvia
KEY REFERENCE			PPT from Sigita Šulca (2012)
WEBPAGE			
CATEGORY			It is a list of criteria and methodologies to assess the impact (significance) on the ecological status of some artificial structures/activities
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	NOT AVAILABLE
		Field survey	NOT AVAILABLE
		Rapid field assessment	NOT AVAILABLE
		Existing database	The method uses data from several organisations: the Latvian Environment, Geology and Meteorology Centre, the National Environmental Service, Marine and Inland Waters Administration, the Ministry of Agriculture, etc.
		Modelling	NOT AVAILABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The assessment is done at sub-catchment scale
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT AVAILABLE
		Scaled to channel width	NOT AVAILABLE
		Variable length	NOT AVAILABLE
	LATERAL SPATIAL SCALE	Channel	The channel zone is considered in the evaluation
		Banks/Riparian zones	The banks and riparian zone are considered in the evaluation
		Floodplain	Only land use in the floodplain is considered in the evaluation
C - TEMPORAL SCALE		Physical and morphological assessment	It assesses present hymo changes (but sometimes linked to past changes, e.g. dam establishment history)
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	NOT APPLICABLE
		Assessment by index	NOT APPLICABLE
		Deviation from reference	NOT AVAILABLE
		General assessment / Design framework	The assessment is based on 3 main groups of criteria: hydrological regime, morphological condition and tidal change regime. It considers 3 main types of impact on hydromorphology: navigation, power generation and land use (land drainage)
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT AVAILABLE
		Links with other systems	NOT AVAILABLE
E - REFERENCE CONDITIONS			NOT AVAILABLE
F - GENERAL INFORMATION	RIVER TYPOLOGY		NOT AVAILABLE
	TYPOLOGY LIMITATIONS		NOT AVAILABLE
	TYPE-SPECIFIC (Protocol / Assessment method)		The assessment takes into account specific impacts on specific component of the system (on groundwater, river, delta, etc.)
	BASIS FOR STANDARDS / THRESHOLDS		The changes take into account are: significant and insignificant changes for river navigation; significant, medium and insignificant changes for power generation and land use
	REACH SCALE SURVEY STRATEGY		NOT AVAILABLE
	TIMING AND FREQUENCY		NOT AVAILABLE
	DATA PRESENTATION (OUTPUT/LAYOUT)		NOT AVAILABLE
	METHOD SUPPORT / APPLICATION TOOLS		NOT AVAILABLE
	SPATIAL COMPARISON		It allows for comparison between sub-catchment
	CONNECTION TO ECOLOGY		Selected hyromorphological criteria are considered important to ensure existence of biological criteria
	USERS		NOT AVAILABLE
	SCALE INFORMATION		It provides information either at local and large (sub-catchment) scales
	NUMBER OF END PARAMETERS		NOT AVAILABLE
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Land use (agriculture) and consequent land drainage changes are assessed at catchment scale. Criteria: % polder in the total sub-catchment; % regulation of total stream length in the sub-catchment; % regulation in the main stem

	HYDROLOGICAL REGIME	Hydrological conditions	Hydrological regime is part of the criteria of assessment (important to ensure the existence of biological criteria). Parameters (criteria): Flow dynamics and volume, period of water exchanges, connection with groundwater (catchment scale), river continuity
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE
	CHANNEL FORMS		Bed cross section
	BED CONFIGURATION		NOT APPLICABLE
	CHANNEL DIMENSIONS		Depth and width variation
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Dominant composition of bed substrate
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Criteria for power generation: barrier to river continuity, assessed on main stem and tributaries; dam history. Criteria for navigation: regular deepening; dredging
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Structure of the shore zone
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Structure of the shore zone
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Bank construction and reinforcement (criteria for navigation)
	LAND USE		NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Land use/drainage criteria: % of polder in the total sub-catchment area
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	River continuity (as criterion for hydrological regime), considered in the assessment of changes caused by power generation plants
		Water flow	
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Land drainage changes are assessed at catchment scale: % polder in the total sub-catchment
		Sediment (and wood) lateral continuity	NOT AVAILABLE
C - BANK EROSION / STABILITY			NOT APPLICABLE
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT AVAILABLE
		Vertical	NOT AVAILABLE
F - VERTICAL CONTINUITY		Groundwater connection	It is one of the criteria of hydrological regime; it is considered at catchment scale
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			Criteria are defined by national law and used in the definition of hydromorphological changes in RBDP (River Basin District Project)
APPLICATION TO ALL WATER BODIES			It applies to water bodies under human pressures (HMWBs and risk WB)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			NOT AVAILABLE
USED TO PREDICT RISK OF DETERIORATION			The methodology aims to assess the significance, due to human impact, of hymo changes on RBDP
USED TO IDENTIFY IMPROVEMENT TARGETS			NOT APPLICABLE
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			The selected criteria to assess the significance of hymo changes are defined, by national law, as important to ensure the existence of biological criteria
KEY STRENGTHS FOR RIVER MANAGEMENT			Direct link to management of RBDP (individuation of main pressure and assessment of the significance of the changes they cause on hydromorphology

Appendix E 14 – Handboek HYMO (The Netherlands)

1 - METHOD BACKGROUND

NAME OR CODE	**Handboek HYMO**
COUNTRY	The Netherlands
KEY REFERENCE	Dam et al. (2007);
WEBPAGE	http://www.scribd.com/doc/82615968/68/Literatuur
CATEGORY	The method carries out an overall hydromorphological assessment (continuity, hydrological regime and morphological conditions) of river, lakes, canals and coastal areas

2 - METHOD CHARACTERISTICS

A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Existing maps and GIS technique are the basic support of the method. Topographic, geomorphological and soil maps (e.g. for the localisation of barriers, to determine channel pattern, land use, etc.); recent groundwater maps and interpolation of topographic maps; use of historical maps to compare the present state (pattern, bank erosion)
		Field survey	The field measurement method is not standard, but depends upon each assessed parameter, e.g.: inventory of barriers to river continuity (weir, dam, etc.); discharge measurement; cross section measurement or profile description. It also uses feature inventorying collected with LAWA method, and several field descriptions (for morphological conditions)
		Rapid field assessment	NOT APPLICABLE
		Existing database	Info on effects of barriers on river continuity; measures at gauged stations; info on groundwater conditions/measures; use of historical cross section, etc.
		Modelling	Modelling/calculation of water level and discharge and other hydro parameters if there is a gauged station
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method provides info either at the overall water body scale and at the local scale (hydro data); it collects also info at the watershed scale (impacts on the drainage network)
	LONGITUDINAL SPATIAL SCALE	Fixed length	Cross profile is suggested at each 200 m; data from LAWA inventory at each 50 0m
		Scaled to channel width	NOT APPLICABLE
		Variable length	In principle all the water body is assessed; hydrological regime data are assessed at specific sites (where data are available) and in relation to the specific measurement (at least one station in the water body)
	LATERAL SPATIAL SCALE	Channel	Info are collected using maps, databases, historical information and LAWA inventory method and for the entire water body
		Banks/Riparian zones	Processes of bank retreat/deposition assessed using maps, databases, historical information, photos and LAWA inventory method. Info are collected for the entire water body. Land use at 20 m from the banktop (5 m for small rivers)
		Floodplain	Assessed using aerial photos + field survey and existing ecotope maps. For undyked rivers/streams: the area at 100 years of return period is considered. For unclear boundary = buffer of 100 m
C - TEMPORAL SCALE		Physical and morphological assessment	The method mainly assesses the current state; it also considers channel pattern changes from an historical reference state, as well as width pattern (erosion)
		Hydrological assessment	Specific temporal scale information to collect hydro data is given for each river types (and in relation to the type of measure)
D - TYPE OF METHOD		Characterization/classification	NOT APPLICABLE
		Assessment by index	NOT APPLICABLE
		Deviation from reference	Only few parameters are assessed in relation to a reference state (e.g. river pattern)
		General assessment / Design framework	The method aims to give an overall assessment of hymo conditions. Each parameter is assessed individually at the water body scale and in several ways: descriptive, as percentage, quality classes. A quality class is finally assigned at each parameter. For parameters which need an individual feature assessment (e.g. barrier for river continuity), each feature is assessed individually and then the worst class is assigned to the water body. In general, 5 point quality classes are used (organised in 3 or 5 level classes); class attribution is made by experts
		Modelling status / Scenario	NOT APPLICABLE

		Final expert judgment	The judgment of experts enters every time in the evaluation process, to assign each parameter to the relative class
		Links with other systems	It is a single system, but it uses data from LAWA (e.g. during cross section measurement, and for channel and banks assessment)
E - REFERENCE CONDITIONS			Experts judgement if a river is in a bad or good state. Not explicit reference to reference conditions, except for: river pattern to which a reference is determined by water authorities and corresponds to a historical state; naturalness of substrate composition is also assessed compared to a reference (but it is an additional parameter)
F - GENERAL INFORMATION	RIVER TYPOLOGY		Rivers are divided into typologies according to the WFD
	TYPOLOGY LIMITATIONS		Apparently the method could not assess rivers with multi-channel pattern, as well as temporal and ephemeral streams
	TYPE-SPECIFIC (Protocol / Assessment method)		The method indicates specific hydrological protocol/measures in relation to river type (e.g. rivers with or without tidal variation influence; rivers with or without strong annual climatic variation). The method applies different measurements in large and small rivers (e.g. cross profile measurements)
	BASIS FOR STANDARDS / THRESHOLDS		The method uses a 5 classes scoring system: 1=very good (reference); 2=good; 3=moderate; 4=poor; 5=bad. The scoring system is based on an expert form: expert gives an explanation for the score given for each parameter. Standardised tables with general scoring guidelines are added, but experts may opt to score differently based on their own expert judgement
	REACH SCALE SURVEY STRATEGY		Reach scale survey strategy is given only for cross section profile measurement
	TIMING AND FREQUENCY		Frequency of survey is given for each parameters (e.g. river continuity each 6 years). Apparently the method is time-consuming
	DATA PRESENTATION (OUTPUT/LAYOUT)		Parameters are presented in quality classes and colour-based maps could be easily produced
	METHOD SUPPORT / APPLICATION TOOLS		The manual gives detailed explanation on parameter measurement and scoring (standardised tables with general scoring guidelines), as well as photos which represent features
	SPATIAL COMPARISON		The system allows for comparison of scores for each parameter between different sites and water bodies
	CONNECTION TO ECOLOGY		It gives indication on the biological components that are influenced by a specific parameter (e.g. for barrier to sediments ---> alteration to normal grain size sorting from upstream to downstream, and consequently effect on macrofauna and macrophytes). The method assesses the continuity for fish communities, as well as barrier passability for target species. The method links the cross section naturalness (asymmetrical and diverse) to high habitat diversity (for fauna and vegetation)
	USERS		The manual is written for water managers and other specialists like hydrologists, ecologists, surveyors and G.I.S.-specialists. In any case, the method needs expert judgment to classify quality parameters
	SCALE INFORMATION		The method provides information mainly at the large scale of the overall water body
	NUMBER OF END PARAMETERS		The 18 parameters are grouped into 6 sub-elements (barrier assessment (relevance and passability), water flow (quantity and dynamics), groundwater interaction, depth and width variations, structure and substrate of the river bed, structure of the riparian (and floodplain) zone, which refer to the 3 main quality elements (WFD). Some parameter is subdivided into sub-parameters for a total of 22 (e.g. barrier relevance is calculated for sediment and fish separately)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Degree of naturalness of the drainage pattern due to intervention at the watershed level (upstream; trans-boundary parameters)
	HYDROLOGICAL REGIME	Hydrological conditions	Water level, discharge, water flow velocity, degree of runoff, natural drainage pattern, tidal characteristics. For rivers with tidal influence: existence of double flow direction, difference between high and low water, relationship between surface volume and tidal volume
		Metrics of hydrological regime	Long-term trend to identify drought, subsidence; water level, discharge annual fluctuations; tidal fluctuations (mean daily value); highest/lowest water level; fluctuation in water velocity

		Hydro-peaking	NOT AVAILABLE
	VALLEY FORM / FEATURES		Groundwater conditions at the valley and floodplain scale
B - CHANNEL	CHANNEL PATTERN / PLANFORM		River pattern (degree of sinuosity, braiding pattern); Possibility of natural meandering
	CHANNEL FORMS		NOT APPLICABLE
	BED CONFIGURATION		NOT APPLICABLE
	CHANNEL DIMENSIONS		Depth and width variations (cross section and degree of naturalness)
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		Flow velocity and hydrological parameters
	SUBSTRATE		Degree of naturalness of bed substrate composition (compared to reference)
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		Fallen trees are considered as Erosion/sedimentation structures
	ARTIFICIAL FEATURES AND STRUCTURES		Presence of artificial bed structures (concrete, soil cribs, solid layers, etc.); sediment and fish continuity barriers: locks, weirs, dams and storm surge, traps, sand trap (determined also during cross profile)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Cross section and degree of naturalness; Erosion/sedimentation structures - location and size, as well as judgment (sand and gravel banks, swallowing, steep edges, fallen trees)
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		NOT APPLICABLE
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE (but in part from banktop land use)
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Info on natural land use on banktop (coniferous, deciduous)
	ARTIFICIAL FEATURES AND STRUCTURES		Cross section and degree of naturalness; presence and inventory (% of bank length) of bank protection structure (groynes, rip-rap for bank protection, timber piling, quay walls, willow, etc.), determined also during cross profile
	LAND USE		Bank land use (descriptive; 20 m from the banktop and 5 m for small rivers) using photos, field survey and existing ecotope maps
D - FLOODPLAIN	FLUVIAL FORMS		Degree of natural inundation
	INFO ON FLOODPLAIN FEATURES		Possibility of natural meandering
	LAND USE		Floodplain/valley land use: cultivated fields, pasture production, production forest, natural forest, ruderal, reed beds, roads (% land use in classes)
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Presence of barrier for sediment (Number, location and relevance of barriers). It is assessed qualitatively
		Water flow	Presence of barrier for fishes (Number, location and relevance) and barrier passability/accessibility for target species. Both are assessed qualitatively. Degree of runoff (qualitatively assessed, or by calculating the length affected by barrier/total length and then assigning classes)
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Degree of natural inundation: obtained from historical maps, photos and info and land use; calculated as the percentage of length of the water body that is influenced by dams, dikes and embankments parallel to the axis of the river (and then divided in classes)
		Sediment (and wood) lateral continuity	NOT APPLICABLE
C - BANK EROSION / STABILITY			From the cross section naturalness and the presence of bank protection structures; Erosion/sedimentation structures
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	Assessment of lateral channel erosion/sedimentation using historical data/map/photos; assessment of pattern change; descriptive assessment (and then classes) of possibility of natural (free) meandering in the floodplain
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	Groundwater level conditions (amongst hydrological regime parameters)
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method indicates how to perform monitoring and analysis of the hydromorphological conditions trough a set of hydromorphological parameters that are primarily based on

	the European hydromorphological quality elements (Continuity, Hydro regime, morphological conditions) and uses a 5 points quality classes system
APPLICATION TO ALL WATER BODIES	The method applies to all water types and water bodies at least in The Netherlands
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES	It can be used in the classification of any status class
USED TO PREDICT RISK OF DETERIORATION	The method indicates intervals between each measurement (for each parameter), therefore it could be used for this purpose
USED TO IDENTIFY IMPROVEMENT TARGETS	NOT APPLICABLE
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS	It could be used for this purpose given that it indicates, for each parameter, its relation to biological components
KEY STRENGTHS FOR RIVER MANAGEMENT	It has been explicitly developed for water managers. The manual explains in detail how monitoring and analysis of the hydromorphological conditions could be carried out. It could be applied to all river types in The Netherlands

Appendix E 15 – MHR (Poland)

1 - METHOD BACKGROUND			
NAME OR CODE			**MHR - River Hydromorphological Monitoring**
COUNTRY			Poland
KEY REFERENCE			Ilnicki et al. (2009)
WEBPAGE			
CATEGORY			The method aims to assess the overall hydromorphological quality of rivers. It has been developed in Poland based on experiences and assumptions of previously used Polish and international (e.g. RHS) methods
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Existing topographical (1:10000; 1:50000) and ortophoto maps; Google Map and other websites. Together with databases, they represent the main source for the assessment protocol
		Field survey	Field survey must cover 10% of the investigated river, to verify the results of the desk studies protocol. Features that must be identified in the field are: cross section, revetment of the channel, river channel vegetation, structure of the riparian zone
		Rapid field assessment	NOT APPLICABLE
		Existing database	The method uses available data (hydrological and more generic data) from the databases of the Institute for Meteorology and Water Management and the river authorities
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	NOT APPLICABLE (all the main water body is assessed)
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	NOT APPLICABLE
		Variable length	All the river body is assessed (main watercourse, not tributaries)
	LATERAL SPATIAL SCALE	Channel	Assessed in detail
		Banks/Riparian zones	Artificial features are mainly assessed
		Floodplain	Its features and attributes are mainly described
C - TEMPORAL SCALE		Physical and morphological assessment	Only the present state is assessed and compared to a reference one; changes in hydrological regime compared to past mean annual flow are assessed
		Hydrological assessment	Mean annual discharge, flood risk and drought risk: 1961-1980 and 1981-2000
D - TYPE OF METHOD		Characterization/classification	Some attributes are descriptive (25%; e.g. river flow, valley characteristics, catchment size) and do not enter in the status assessment
		Assessment by index	4 main river elements described and/or assessed by 81 attributes, organised in 16 features: 1. hydrological regime (4 features), 2. river continuity (1 features), 3. river morphology (7 features) and 4. valley (4 features). Each of the 81 attributes is scored in a scale from 0 (bad state) to 5 (very good). Attribute scores are summed and compared (rated) to reference conditions to obtain the score for each river feature. Features scores are averaged to obtain the sub-index for each of the 4 elements. The quality index is calculated as the average of the score of 4 elements (not weighted)
		Deviation from reference	The method complies with WFD requirements and relates the settled status to reference status (natural) = anthropogenic unchanged watercourse
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	NOT APPLICABLE
E - REFERENCE CONDITIONS			It identifies the existent state in Poland from the mid-twentieth century before the intensification of agriculture as a natural state (Ilnicky et al., 2010b). In the method, reference conditions are related to natural watercourses which have been classified on the basis of EQR in the upper interval of the very good status (Ilnicky et al., 2010b).
F - GENERAL INFORMATION	RIVER TYPOLOGY		Similar to Germany: 26 river types, but not used in the assessment protocol
	TYPOLOGY LIMITATIONS		No typology limitation, at least for Polish river types

	TYPE-SPECIFIC (Protocol / Assessment method)		Only type-specific limitations for quality classes (natural: 5 classes; HMWBs and AWBs: 4 classes); in principle the method applies to all river bodies, but a different (simplified) protocol has been proposed to assess artificial water bodies
	BASIS FOR STANDARDS / THRESHOLDS		Each of the 81 attributes is evaluated (or in some cases only described) in as scale from 0 (bad state) to 5 (very good), in relation to defined reference conditions; scores for each features (sum of scores of a group of attributes) are normalized to the maximum possible value (reference state) to obtain a point scale from 0 (bad) to 1 (reference); limit of the classes are differentiated for natural, heavily modified and artificial watercourses
	REACH SCALE SURVEY STRATEGY		NOT APPLICABLE
	TIMING AND FREQUENCY		NOT APPLICABLE
	DATA PRESENTATION (OUTPUT/LAYOUT)		4 quality sub-Indices (4 elements) and a final index (water body scale). Data collected have to be compiled in a special database and used to develop maps (five colour coded maps)
	METHOD SUPPORT / APPLICATION TOOLS		The basic document is a few page office protocols (the same for natural and HMWBs); a simplified protocol for AWBs
	SPATIAL COMPARISON		Comparison is possible given that the method does not relate to specific river types, but only amongst natural rivers or HBWBs or AWBs
	CONNECTION TO ECOLOGY		The method relates to data supplied by other ecological surveys (for river's ecological status). It also assesses the length of water body (%) with limited possibility of fish migration and river shading and the % of protected valley areas
	USERS		NOT AVAILABLE (apparently wide use)
	SCALE INFORMATION		Water body scale information is collected and assessed; larger scale information concerns catchment size and flow characteristics
	NUMBER OF END PARAMETERS		4 main elements, described by 16 features, organised in 81 attributes. Main elements: hydrological regime (4 features), river continuity (3 features), river morphology (7 parameters) and valley characteristics (4 features)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Descriptive form: catchment size. evaluation/scoring form: flow disturbance (reservoirs, uptake, transfer, etc.)
	HYDROLOGICAL REGIME	Hydrological conditions	Descriptive form: specific flow; degree of human pressure on stream gauge records; mean annual discharge; minimum flow. Evaluation/scoring form: changes in mean annual discharge, flood and drought risk changes
		Metrics of hydrological regime	Minimum annual discharge, mean annual discharge, high annual discharge
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		Descriptive form: valley characteristics (cross-section)
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Evaluation/scoring form: sinuosity index; number of channels
	CHANNEL FORMS		Evaluation/scoring form: cross profile (Presence of natural channel forms)
	BED CONFIGURATION		Descriptive form: presence of waterfall. Evaluation/scoring form: variability of longitudinal slope
	CHANNEL DIMENSIONS		Descriptive form: channel width, average longitudinal slope
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Descriptive form: predominant sediment composition, group of abiotic types
	IN-CHANNEL VEGETATION		Evaluation/scoring form: river channel vegetation (% cover)
	WOODY DEBRIS		Descriptive form: fallen trees. Evaluation/scoring form: presence of coarse wood debris
	ARTIFICIAL FEATURES AND STRUCTURES		Descriptive form: bridge with piles in the channel, waterway with sluice, damming structure. Evaluation/scoring form: revetment of the channel (reinforcing structures, movement of sediment), range of river regulation, water uptake, transfer and retention
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Evaluation/scoring form: cross section (profile regularity, bank slope, slope)
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Evaluation/scoring form: structure of the riparian zone
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Evaluation/scoring form: riparian zone continuity
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	Evaluation/scoring form: presence of numerous exposed roots on the bank, shading
	ARTIFICIAL FEATURES AND STRUCTURES	Descriptive form: river embankments (%). Evaluation/scoring form: reinforcing structures
	LAND USE	Evaluation/scoring form: annual bank cutting and plant removal; % of areas not used for farming
D - FLOODPLAIN	FLUVIAL FORMS	Evaluation/scoring form: % of periodically flooded areas
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	Descriptive form: Predominant land use; location of river, road and railway embankments. Evaluation/scoring form: % of natural, grassland, developed areas, etc.
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood	It records the presence of damming structure; it assesses the in-channel sediment mobility (erosion, clogging, etc.). It assesses the length of water body (%) with limited possibility for fish migration
	Water flow	It records the presence of damming structure and assesses water uptake, transfer and retention, as well as changes in hydrological regime
B - LATERAL CONTINUITY	Lateral hydraulic continuity	It records the level of flood protection (embankments etc.) and assesses the % of periodically flooded areas, as well as changes in hydrological regime
	Sediment (and wood) lateral continuity	It assesses the width of the inter-embankment zone
C - BANK EROSION / STABILITY		It could be indirectly assessed from information on bank profile
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	Descriptive form: number of groundwater bodies. Evaluation/scoring form: % of ground runoff; status connection to groundwater
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method has been developed to specifically comply with the WFD requirements (and following directives) and it has been officially approved for the hydromorphological river assessment in Poland
APPLICATION TO ALL WATER BODIES		It applies to all water types and to natural and HMWBs; a simplified protocol exists for AWBs
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It is used to calculate both the ecological quality index (natural watercourses/water bodies) and the ecological potential (artificial/heavily modified watercourses/water bodies)
USED TO PREDICT RISK OF DETERIORATION		Potentially used (see information on changes in hydrological regime)
USED TO IDENTIFY IMPROVEMENT TARGETS		The calculation of EQR for all features allows for the identification of factors that prevent the attainment of a good ecological status and, therefore, requiring recovery measures
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		It could be potentially used for this purpose given that the method relates to data supplied by other ecological surveys (for river's ecological status)
KEY STRENGTHS FOR RIVER MANAGEMENT		A simple method characterized by low cost and low labour intensity and which widely covers WFD requirements

Appendix E 16 – RHS adaptation (Portugal)

1 - METHOD BACKGROUND			
NAME OR CODE			**RHS adaptation (in progress)**
COUNTRY			Portugal
KEY REFERENCE			Raven et al. (2009); Ferreira et al. (2011)
WEBPAGE			
CATEGORY			The method aims to assess the physical habitat quality of rivers in Portugal (modifications/adaptations of the UK-RHS to hydromorphological conditions in Portugal)
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	The authors highlight the importance of aerial photographs to verify and interpret RHS survey data and to define riparian habitat distribution and land uses
		Field survey	The same protocol as for RHS
		Rapid field assessment	NOT APPLICABLE
		Existing database	Use of existing database to calibrate the method to Portugal
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Same as to RHS
	LONGITUDINAL SPATIAL SCALE	Fixed length	Same as RHS
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	More attention and adaptation to specific channel features (natural and artificial) of Mediterranean rivers
		Banks/Riparian zones	More attention to extent of trees and associated features in the riparian zone; re-definition of banktop; clearer definitions of natural berm, terrace and riparian floodplain
		Floodplain	Inclusion of typical land use in Portugal; much clearer definitions of natural berm, terrace and riparian floodplain
C - TEMPORAL SCALE		Physical and morphological assessment	Same as RHS
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	Same as RHS
		Assessment by index	Modification/adaptation of HQI and HMS to rivers in Portugal
		Deviation from reference	Consistent with RHS but specific description of type-specific reference conditions in Portugal are needed
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	Possible link and parallel use to QBR and other hydrological assessment methods (because RHS lacks them)
E - REFERENCE CONDITIONS			Authors need to describe type-specific reference conditions for Portugal, but rare examples seem to exist in Portugal
F - GENERAL INFORMATION	RIVER TYPOLOGY		Authors will provide the development and validation of a national river typology (but nationally it is used the system B, (INAG, I.P., 2008))
	TYPOLOGY LIMITATIONS		The method would accomplish lacks of RHS in terms of assessment of Mediterranean rivers; it is specifically adopted to be applied to river types in Portugal
	TYPE-SPECIFIC (Protocol / Assessment method)		NOT APPLICABLE
	BASIS FOR STANDARDS / THRESHOLDS		Under development
	REACH SCALE SURVEY STRATEGY		Same as RHS
	TIMING AND FREQUENCY		Particular attention should be given to the period of survey, because of the high variability in hydrological regimes in Portugal (Seasonal and inter-annual flow variability, both for natural and human-induced causes)
	DATA PRESENTATION (OUTPUT/LAYOUT)		Same as RHS
	METHOD SUPPORT / APPLICATION TOOLS		A Portuguese support protocol version (manual, field sheets, database etc.) is under development
	SPATIAL COMPARISON		Modifications to the original RHS protocol will be limited, allowing comparison of data between different EU Member States that use RHS
	CONNECTION TO ECOLOGY		Same as RHS
	USERS		Same as RHS
	SCALE INFORMATION		Same as RHS
	NUMBER OF END PARAMETERS		NOT AVAILABLE
3. RECORDED FEATURES			

A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Same as RHS
	HYDROLOGICAL REGIME	Hydrological conditions	Consistent with RHS; surveyors are always required to record the conditions of the survey to allow for comparison
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		Consistent with RHS; problems to determine banktop in V-shaped valleys
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Same as RHS
	CHANNEL FORMS		The Portuguese version records some additional features of channel forms (total number of side bars; the presence and number of wet and dry sub-channels; distinguish mid-channel bars and mature islands surrounded by dry/ wetted sub-channels)
	BED CONFIGURATION		Adding "presence of vernal pools" (dry channels) amongst features of special interest
	CHANNEL DIMENSIONS		Re-definition of criteria to determine and define banktop
	FLOW-TYPE		It better defines/explains naturally-ponded flow-type and provides keys to identify modifications causing ponded water
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Consistent with RHS but it records either the dominant and sub-dominant channel substrate (because annual flow variability leads to a high number of substrate types in a site)
	IN-CHANNEL VEGETATION		Channel vegetation types description adapted to rivers in Portugal
	WOODY DEBRIS		Same as RHS
	ARTIFICIAL FEATURES AND STRUCTURES		Improved description of artificial features and their actual impact (i.e. minor fords and weirs), difficult to describe during low flows
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		It needs to define discrete sit/sand/gravel deposit as bankside depositional features
	BANK MATERIAL		Same as RHS
	RIPARIAN VEGETATION STRUCTURE		Same as RHS
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Same as RHS
	RIPARIAN VEGETATION WIDTH		Differently from the RHS protocol, the Portuguese version directly assesses the width of the riparian zone (both banks)
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Presence/Absence/Extension of typical fluvial woody species and "nuisable" plant species
	ARTIFICIAL FEATURES AND STRUCTURES		Same as RHS
	LAND USE		Definition of land uses adapted for Portugal
D - FLOODPLAIN	FLUVIAL FORMS		Same as RHS
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Definition of land uses adapted for Portugal; add "Riparian (wet) woodland" amongst floodplain land uses
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Same as RHS
		Water flow	Same as RHS
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Same as RHS
		Sediment (and wood) lateral continuity	Same as RHS
C - BANK EROSION / STABILITY			Same as RHS
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	Same as RHS
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method is an implementation of the RHS methodology for fluvial hydromorphological characterization and quality assessment in Portugal in accordance with the WFD and with a work plan defined by Portuguese Water Authorities to achieve this objective
APPLICATION TO ALL WATER BODIES			It is applied to all water bodies in Portugal
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			NOT AVAILABLE
USED TO PREDICT RISK OF DETERIORATION			NOT AVAILABLE
USED TO IDENTIFY IMPROVEMENT TARGETS			NOT AVAILABLE
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			NOT AVAILABLE
KEY STRENGTHS FOR RIVER MANAGEMENT			Possibility to compare results at the European scale

Appendix E 17 – MImAS (Scotland)

1 - METHOD BACKGROUND			
NAME OR CODE			**MImAS - Morphological Impact Assessment Method**
COUNTRY			Scotland
KEY REFERENCE			UKTAG (2008)
WEBPAGE			http://www.wfduk.org/
CATEGORY			It is a morphological impact assessment system (tool) which aims to support stakeholders to identify whether morphological alterations/changes (interventions) may cause risk to fail the achievement of ecological objectives (related to WFD). Developed by SNIFFER (Scotland and Northern Ireland Forum For Environmental Research)
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	A desk study is carried out to determine channel type in case there is no typology information in the SEPA River Type database. Maps and aerial photos are also used to identify impacts
		Field survey	To collect data on pressures where needed (Morphological Pressure Survey Guidance). In some cases (high risk; assessment failure; river status falls at class boundary) field survey is needed to support the Desk-study in determining the channel type
		Rapid field assessment	NOT APPLICABLE
		Existing database	It uses data from existing databases in terms of river conditions. It uses database to determine channel types (SEPA River Type database).The SEPA developed a Morphological Pressures Database (MPD) that is a key input for module 4
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	It uses a first bottom-up hierarchical spatial scale assessment system: it starts from an assessment at the local scale (500 m reach; Stage 1) to go to a larger scale (river surrounding catchment; Stage 2). Then, where needed, more detailed regulatory assessments (at smaller scale) are applied
	LONGITUDINAL SPATIAL SCALE	Fixed length	A 500 m local scale is evaluated in the first phase of risk assessment (Stage 1), which aims to identify: 1) low risk proposals that do not threaten ecological status; 2) proposals that exceed morphological limits (which can potential influence the ecological status) and would need the Stage 2 assessment
		Scaled to channel width	NOT APPLICABLE
		Variable length	In the Stage 2 of the assessment (when morphological limits are exceeded by proposed intervention), all the river body can be assessed (Water Body assessment)
	LATERAL SPATIAL SCALE	Channel	Channel zone and banks/riparian zone are assessed separately in terms of the river's capacity to support further morphological change
		Banks/Riparian zones	
		Floodplain	The surrounding catchment is in part taken into account in the Stage 2 of the assessment (but none floodplain attribute is assessed, except connectivity)
C - TEMPORAL SCALE		Physical and morphological assessment	It assesses the present morphological conditions and provides an assessment for further morphological interventions
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	NOT APPLICABLE

	Assessment by index	The method assesses the impact on morphological conditions (system capacity) through 5 semi-independent modules: 1) the attribute module (list of attributes to assess morphological and ecological function and condition); 2) the typology module (to select attributes proper for each river type); 3) the sensitivity module (ecological and morphological sensitivity assessment: resistance and resilience); 4) the pressure module (15 pressures assessed through 2 components: I) assessment of the impact of pressure on morphological attributes, after module 1-2; II) assessment of the impact of the pressure in terms of spatial scale extent = 'zone of impact'); 5) the scoring system (a numerical 'impact rating' by combining results of previous modules). It calculates the '% capacity used' for the section of river considered, given by combining the 'impact rating' to the alteration footprint (type of alteration and affected river length) calculated for that river length, and then added for all morphological alterations. The '% capacity used' is compared to limits for Environmental Standards (also called MCLs = morphological conditions limits), to assess the risk to ecological status. The method takes into account also the effect of a single discrete alteration that may have impact on the ecological integrity, even if the sum of alteration along the entire water body does not impact the ecological status
	Deviation from reference	NOT APPLICABLE
	General assessment / Design framework	It is a decision-making framework: 1) to support river engineering activity in accord to WFD requirement; 2) to assess if present morphological alterations are compatible with the achievement of WFD objectives (good and high ecological status). It does not make a quantitative inventorying
	Modelling status / Scenario	It models the risk of impact for morphological and ecological status considering changes in pressure (new impacts)
	Final expert judgment	The expert judgment enters in the assessment process several times: e.g. the assessment of sensitivity (module 3); the Environmental standards are defined/proposed by experts (authors) for each river zone (channel, banks and riparian area)
	Links with other systems	It is a complex protocol assessing: 1) the ecological and morphological sensitivity; 2) the 'impact rating'; 3) the '% capacity used' and compares that to Environmental Standards; 4) the effect of single discrete alterations
E - REFERENCE CONDITIONS		NOT APPLICABLE
F - GENERAL INFORMATION	RIVER TYPOLOGY	The module 2 (Typology module) identifies 6 river types on the basis of river morphological similarities (from high energy to low energy rivers) and as function of their response to morphological alteration. This module is used to select significant attributes of module 1 (the attribute module), relevant for the assessment of a given river type, and to assess river sensitivity (module 3). The method considers that the response of a rivers morphology to an engineering or other pressure is predictable for that type of water body
	TYPOLOGY LIMITATIONS	It applies to the 6 identified river types. It directly applies to river that are longer than 5 km; for rivers less than 5 km long, the method must be applied in conjunction with another water body on the same tributary/main stem (to reach 5 km). Apparently it does not apply to temporary streams
	TYPE-SPECIFIC (Protocol / Assessment method)	Specific attributes are used to assess specific river types. River types are used to make the preliminary assessment of the river sensitivity (Module 3; morphological and ecological sensitivity). In the module 4 (pressure module), not type specific, differences between types are derived by combining river type sensitivity and type of pressure. Each morphological alteration (pressure module n. 4) has its own impact rating, which is specific to each channel type
	BASIS FOR STANDARDS / THRESHOLDS	The 'impact rating' = combining info obtained from each module (3 modules: typology * ecological sensitivity * morphological sensitivity * impact of pressure on attribute); the rating is calculated for each attribute and then averaged for channel, banks and riparian zone; the value is multiplied for impact zone to get an overall impact rating for each morphological alteration. Environmental standards are given in terms of '% capacity used', where the system capacity is defined as the ability to absorb morphological variations without affect the ecological integrity. Environmental Standards are defined/proposed by authors for each river zone: higher morphological conditions are, lower is the % capacity used (condition limits are not type specific)

	REACH SCALE SURVEY STRATEGY		During the Stage 1 all the 500 m reach is assessed; in general the assessment depends upon the extent (L) of morphological alteration considered
	TIMING AND FREQUENCY		NOT AVAILABLE
	DATA PRESENTATION (OUTPUT/LAYOUT)		A final PDF report (from the Oracle software) is obtained which summarises all versions of the current assessment calculations (predicted morphological status, '% capacity used', the risk of deterioration assessment)
	METHOD SUPPORT / APPLICATION TOOLS		An Oracle-based application and a database containing the present state of surveyed reaches; Morphological Pressure Survey (MPS) Guidance; Morphology Pressures Database (MPD)
	SPATIAL COMPARISON		It allows for comparison between same river types
	CONNECTION TO ECOLOGY		The connection is either direct and not. the method aims to support ecological assessment (surrogate for robust ecological assessment methods). It assumes the existence of a relationship between the extent of morphological alteration and the impact on ecological status. The assessment of ecological sensitivity (module 3) considers whether a degradation of community or species integrity is likely to occur in response to a disturbance to individual attributes, and for each river type (attributes of module 1)
	USERS		It has been developed to be used by non-experts
	SCALE INFORMATION		It provides reach scale information (500 m length) and water body scale information, according to the type of assessment
	NUMBER OF END PARAMETERS		5 modules. Module 1 (attributes): 2 main groups of parameters according to fluvial zones (channel and banks/riparian area) and several parameters. Module 2 (typology): 6 channel types. Module 3 (sensitivity): divided into 2 parts, ecological (all WFD BQEs) and morphological (for each attribute and river type). Module 4 (pressure): between 15 and 25 different types of pressures are included; either 'type of impact' (likelihood) and 'zone of impact' are considered. Module 5 (the scoring system): 'impact rating' (from previous modules), '% capacity used' (impact rating, footprint of the alteration, reach length)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Large scale characteristics are intrinsic in the channel typology definition (e.g. geology, slope, confinement)
	HYDROLOGICAL REGIME	Hydrological conditions	NOT APPLICABLE
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Hydraulic geometry (planform)
	CHANNEL FORMS		Hydraulic geometry (planform, cross section); erosion/deposition character (bar character)
	BED CONFIGURATION		Hydraulic geometry (cross section, profile); erosion/deposition character (bedform pattern)
	CHANNEL DIMENSIONS		NOT AVAILABLE
	FLOW-TYPE		NOT AVAILABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Substrate conditions (size, embeddedness, compaction)
	IN-CHANNEL VEGETATION		In-channel vegetation (structure and extent of in-stream vegetation)
	WOODY DEBRIS		In-channel vegetation (structure and extent of woody debris)
	ARTIFICIAL FEATURES AND STRUCTURES		E.g. bed modification/reinforcement; sediment removal; culvert, pipes, flow deflectors; bridge piles; impoundment; channel straightening
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Banks and riparian zone (bank morphology; bank roughness)
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Banks and riparian zone (riparian vegetation structure)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		E.g. embankments and set-back embankments (< and > 10 m from the channel respectively); alteration of riparian vegetation structure complexity (e.g. removal, total and/or partial); bank revetment/reinforcement (soft = with vegetation; hard = without vegetation)

	LAND USE	NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS	NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	NOT APPLICABLE
4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood Water flow	The method assesses the impact of impoundments. Longitudinal connectivity (sediment transport, migratory movement)
B - LATERAL CONTINUITY	Lateral hydraulic continuity	The method assesses the impact of minor and major embankments. Floodplain connectivity is taken into account
	Sediment (and wood) lateral continuity	The method assesses the impact of the alteration of vegetation structure (vegetation and wood removal). Floodplain connectivity is taken into account
C - BANK EROSION / STABILITY		Erosion/deposition character
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	Erosion/deposition character (lateral rate of adjustment)
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		It is the tool used for WFD classification in Scotland by the SEPA
APPLICATION TO ALL WATER BODIES		HMWBs and AWBs are not considered
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It has been developed to identify whether morphological changes could threaten the achievement of good ecological status, as well as to allow the assessment of high status
USED TO PREDICT RISK OF DETERIORATION		It has also been developed for this purpose
USED TO IDENTIFY IMPROVEMENT TARGETS		It has been developed to identify when deteriorations of status may need to be managed
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		It is also a tool to allow for the assessment of risk of failing the Good ecological status
KEY STRENGTHS FOR RIVER MANAGEMENT		It can be used to support the feasibility of engineering works, through the assessment of risk that an intervention may cause in terms of morphological (and then ecological) impact; it is practicable and not time-spending (not inventorying)

Appendix E 18 – HAP-SR (Slovakia)

1 - METHOD BACKGROUND			
NAME OR CODE			**HAP-SR - Hydromorphological Assessment Protocol for the Slovak Republic**
COUNTRY			Slovakia
KEY REFERENCE			NERI & SHMI (2004); Lehotský & Grešková (2007)
WEBPAGE			
CATEGORY			The protocol aims to monitor and assess the hydromorphological quality elements of rivers for the definition of the ecological status. It derives from a draft Slovak protocol developed by Adamkova et al. (2004) and based on the German ESLR (Bundesanstalt für Gewässerkunde, 2001)
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Maps (topographic, historical, geological, vegetation), aerial photographs, GIS layers (e.g. land use) are collected during the first step of data collection. Maps are also used to help in defining reaches and reference conditions. Maps are used to assess map-based parameters (historical changes and large scale characteristics)
		Field survey	It is carried out in the Survey Unit (SU) defined on maps. Map survey parameters must be checked in the field. Three survey forms are used for each SU: one "site protocol" and two "assessment forms" (one for morphology, one for hydrology)
		Rapid field assessment	NOT AVAILABLE
		Existing database	It uses hydrological time series, data on reservoir management, water abstraction
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method assesses river reaches by a hierarchical spatial scale analysis: the basic unit is the survey unit (SU), divided into 5 sub-survey units (SSU); the location of the survey depends on the environmental variation along the defined reach
	LONGITUDIN AL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	SU and SSU are scaled to river size; the SU is representative of the river (with respect to channel morphology, land use, geology and geomorphology)
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	All the stream channel is assessed
		Banks/Riparian zones	Riparian vegetation is assessed in a 20-meter wide zone along both sides of the river
		Floodplain	The floodplain parameters are based on the whole floodplain
C - TEMPORAL SCALE		Physical and morphological assessment	The method assesses the present state, as well as historical changes (e.g. channel pattern, river regime)
		Hydrological assessment	The method assesses changes in mean and low flow, flow range and flow fluctuation
D - TYPE OF METHOD		Characterization/classification	The method collects a certain number of parameters useful to characterize he overall landscape features at the sites and in the catchment. The "site protocol" is divided into 5 parts: identification, channel parameters, riparian and floodplain features, catchment features and hydrological parameters (36 in total)
		Assessment by index	Two main groups of parameters are assessed: morphological (divided into 4 categories) and hydrological (4 parameters) parameters: a score from 1 (best) to 5 (worst) is assigned to each parameter. For the morphology: each parameter is averaged between SUU to obtain a SU score (for the parameter). SU parameters values for each category are averaged to have a SU category score; the average between categories, gives the morphological value for the SU. For the hydrology: the final score is the average of the 4 parameters scores. 2 final indices (quality classes), 1 for morphology, one for hydrology
		Deviation from reference	The method compares the quality status to the corresponding reference condition, by using the assessment parameters (not for "site protocol" parameters)
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE

		Final expert judgment	Expert judgement helps during the map-based assessment where map data are unavailable (transfer of data or knowledge from similar sites), or to assess particular features such as changes of hydrological regime, presence of migration barriers
		Links with other systems	NOT APPLICABLE
E - REFERENCE CONDITIONS			It is the original state of the river before it was affected by human influences (empirical/historical state). It corresponds to the maximum obtainable range of values within the high ecological status band, according to stream type
F - GENERAL INFORMATION	RIVER TYPOLOGY		Typology and reach definition are not included in the protocol (given that they are part of the implementation of the WFD)
	TYPOLOGY LIMITATIONS		No typology limitation, at least in Slovakia
	TYPE-SPECIFIC (Protocol / Assessment method)		It covers all stream types in Slovakia
	BASIS FOR STANDARDS / THRESHOLDS		Parameters are scored from 1 (reference) to 5 (worst). Sub-indices and 2 main indices are obtained as mean values. It is proposed an "a posteriori" graduation of reference scores and thresholds calibration. Division in quality bands should also be verified using field trials and making a sensitivity analysis (the deviation between results of the assessment protocol and results of expert assessment)
	REACH SCALE SURVEY STRATEGY		The survey unit (reach) is subdivided into 5 sub-units of equal length and they are surveyed by walking along the river or wading it (e.g. by boat for larger rivers)
	TIMING AND FREQUENCY		Surveys should be carried out during low flow and in the vegetation period
	DATA PRESENTATION (OUTPUT/LAYOUT)		Compiled field protocols, photos about features, indices (sub-indices for parameters at SU, for categories at SU and for main groups at SU), quality classes
	METHOD SUPPORT / APPLICATION TOOLS		Guidance on sample site selection, a map based protocol, field procedures (site protocol and 2 assessment forms), scoring system, a guidance on training, accreditation and intercalibration procedures
	SPATIAL COMPARISON		Most parameters collected during the site protocol can be used to group streams with identical features, enabling comparison of hydromorphological and biological parameters among similar streams
	CONNECTION TO ECOLOGY		Specific biological indicators need to be identified and linked to results of the hymo protocol. The method assesses and characterizes the effect of the presence of migration barriers (and fish pass where present)
	USERS		Training, accreditation and inter-calibration are needed to avoid subjectivity
	SCALE INFORMATION		The method provides information at catchment scale, water body scale and reach scale
	NUMBER OF END PARAMETERS		For the Site protocol: 5 categories and 36 parameters described in total. For the Assessment form: 2 main groups, 4 categories (for the 1st group) and 18 parameters in tot (14 for the 1st + 4 for the 2nd main group)
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Assessed during the map based assessment (e.g. floodplain structure, catchment land use, stream order, site altitude, distance to source, mean slope, river use, geology, soil type, minimum and maximum elevation)
	HYDROLOGICAL REGIME	Hydrological conditions	Mean annual discharge, Changes to the hydrological regime (due to groundwater and/or surface water abstraction)
		Metrics of hydrological regime	Mean flow (scored), low flow (scored), water level range (scored), frequent flow fluctuations (scored)
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		River valley form/type (map based assessment)
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Present/dominant channel planform, sinuosity (scored), channel type (scored), channel shortening (scored), spatial variation in width (scored)
	CHANNEL FORMS		Bed elements (SSU, scored)
	BED CONFIGURATION		Bed elements (SSU, scored)
	CHANNEL DIMENSIONS		Cross section dimension (channel width, bankfull width depth width, width/depth variation)
	FLOW-TYPE		Flow type diversity (SSU, scored)
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		The score concerns: Number of river bed substrate, mud covers and presence of artificial substrate (SSU)
	IN-CHANNEL VEGETATION		Macrophytes coverage

	WOODY DEBRIS		Presence/abundance of large woody debris (scored)
	ARTIFICIAL FEATURES AND STRUCTURES		Presence of migration barriers, presence of artificial bed features (SSU, scored)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Cross-section type, Naturalness of bank profile (SSU, scored)
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		Naturalness of riparian vegetation (SSU, scored); Tall herbs/shrubs (coverage)
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Natural/non-natural isolated tree (coverage), Natural/non-natural closed line (coverage)
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Non-natural vegetation in 20 m riparian zone (assessment and coverage)
	ARTIFICIAL FEATURES AND STRUCTURES		Extent of bank stabilization (scored)
	LAND USE		Non-natural vegetation in 20 m riparian zone (assessment and coverage)
D - FLOODPLAIN	FLUVIAL FORMS		Non-natural vegetation in 20 m riparian zone (assessment and coverage)
	INFO ON FLOODPLAIN FEATURES		Flooded area compared to historical (SSU, scored); Extent of natural floodplain vegetation (SSU, scored)
	LAND USE		Predominant land use on floodplain (assessed)
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Characterization of barrier for migration
		Water flow	The method assesses changes in water discharge (due to dam, hydropower operations, water abstraction, industrial outlets)
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Evaluated through the assessment of cross profile changes, presence of embankments, and modification in flow regime
		Sediment (and wood) lateral continuity	Size (percentage) of present natural floodplain area is compared to potential (historical)
C - BANK EROSION / STABILITY			Bank stabilisation, compared to reference past state, is assessed at the SSU level
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	The method assesses channel shortening, changes in channel pattern and planform
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	Changes in water discharge due to groundwater water abstraction is described
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The protocol development was part of a project (TWINNING) aiming to the harmonization of water legislation of the Slovak Republic with the regulations of the European Union (WFD), and to support the definition of the ecological status of rivers. The 2004 version was a proposal of protocol
APPLICATION TO ALL WATER BODIES			The method applies to all water bodies (natural, heavily modified and artificial water bodies)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			It can be used for assessing hydromorphological quality in natural, heavily modified and artificial water bodies
USED TO PREDICT RISK OF DETERIORATION			The assessment relates to past conditions therefore it could be used to predict the risk of deterioration
USED TO IDENTIFY IMPROVEMENT TARGETS			Potentially it could be used for this purpose
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			If opportunely related to biological indicators, it could be used for this purpose; the characterization of migration barrier can help to identify cause of ecological impact for fish communities
KEY STRENGTHS FOR RIVER MANAGEMENT			It has been developed to comply with WFD requirement. It uses either field and remote sensing data, and includes a relatively detailed analysis of hydrological data. The part concerning the site characterization provides information potentially useful for other scopes

Appendix E 19 – SIHM (Slovenia)

1 - METHOD BACKGROUND			
NAME OR CODE			**SIHM**
COUNTRY			Slovenia
KEY REFERENCE			Tavzes & Urbanic (2009)
WEBPAGE			
CATEGORY			The method aims to assess the overall hydromorphological status (habitat quality and modification, hydrological modification and general hydromorphological status) and to link it with benthic invertebrate community characteristics. It has been developed/modified from RHS
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	It uses Slovenian map of river catchments classes for the hydrological modification assessment
		Field survey	Consistent with RHS
		Rapid field assessment	Consistent with RHS
		Existing database	Existing information on water quality (pollution) used to determine reference sites
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	Consistent with RHS
	LONGITUDINAL SPATIAL SCALE	Fixed length	Consistent with RHS
		Scaled to channel width	NOT APPLICABLE
		Variable length	NOT APPLICABLE
	LATERAL SPATIAL SCALE	Channel	Consistent with RHS
		Banks/Riparian zones	Consistent with RHS
		Floodplain	Consistent with RHS
C - TEMPORAL SCALE		Physical and morphological assessment	Consistent with RHS
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	The feature inventorying is done by using the RHS protocol
		Assessment by index	Several indices have been developed to be applied to data collected with the RHS protocol. MORPHO STATUS: River habitat quality index (RHQ); River habitat modification index (RHM). HYDRO STATUS: Hydrological modification index (HLM). HYMO STATUS: Hydromorphological modification index (HMM); Hydromorphological quality and modification index (HQM). A specific weight has been assigned to each morphological feature recorded in the survey, in order to consider not only their presence/absence/frequency but also their influence on benthic invertebrate communities. MORPHO STATUS: features are grouped in 7 main variables: 1) bank, 2) channel, 3) riparian, 4) land use within 50 m; 5) features of interest along 500 m, 6) bank modifications, 7) channel modifications. RHQ: calculated through variables 1 to 5. RHM: calculated with 6 and 7. HYDRO STATUS: HLM: calculated either for the main course and tributaries, considering catchment size's classes either for inflowing tributaries and river at confluence; the final index at site considers HLM for both (main channel and tributaries). HYMO STATUS: HMM: multimetric index, combination of weighted values of RHM and HLM. HQM: combination of weighted values of RHQ, RHM and HLM
		Deviation from reference	It uses reference conditions to normalize values of RHQ and RHM and to calculate HQM index
		General assessment / Design framework	The method makes a general assessment of hydromorphological status
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	Expert judgment is used to weight values for features
		Links with other systems	The method develops several indices, for the assessment of physical habitats status and for hymo status. Hymo status is obtained as a combination of indices (status = quality and modification)
E - REFERENCE CONDITIONS			Reference sites corresponds to sites where the sum of habitat modification scores (HMS) does not exceed 5 points and if they have been classified at least as good regarding water pollution; then, they are confirmed by comparison of RHQ values between reference and impaired sites

F - GENERAL INFORMATION	RIVER TYPOLOGY		In Slovenia, in the hydro-ecoregion Alps (where the method has been tested and developed), 26 different national river types have been identified (using system B) ranging from small to medium and large rivers
	TYPOLOGY LIMITATIONS		The method has been developed and applied to Slovenian river types of the hydro-ecoregion Alps
	TYPE-SPECIFIC (Protocol / Assessment method)		Specific catchment size has been considered to evaluate the effect of major impoundment (length impoundment vs catchment size)
	BASIS FOR STANDARDS / THRESHOLDS		The assigned weighting values have been chosen considering expert judgment or literature sources. Values have been determined considering if features increase/decrease habitat diversity and have a positive/negative effect on macrobenthos
	REACH SCALE SURVEY STRATEGY		Consistent with RHS
	TIMING AND FREQUENCY		Consistent with RHS
	DATA PRESENTATION (OUTPUT/LAYOUT)		Description of features, index values
	METHOD SUPPORT / APPLICATION TOOLS		The RHS manual; indications on how calculate indices
	SPATIAL COMPARISON		It allows for comparison between considered river types
	CONNECTION TO ECOLOGY		The method in its phase of development has been tested on macrobenthos fauna. Features have been weighed to consider their influence on benthic invertebrate communities
	USERS		Consistent with RHS
	SCALE INFORMATION		Consistent with RHS
	NUMBER OF END PARAMETERS		33 assessment variables. 22 for RHQ: 8 bank features; 7 channel features; 4 riparian features; 1 features of land use within 50m; 2 features of special interest. 11 for RHM: 3 bank features modification; 8 features for channel modification
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		Consistent with RHS and info on catchment impoundment structures
	HYDROLOGICAL REGIME	Hydrological conditions	For the survey of hydro properties the method considers the distance from the impoundment and the number of tributaries between the impoundment and the site
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		Same as RHS
B - CHANNEL	CHANNEL PATTERN / PLANFORM		Same as RHS
	CHANNEL FORMS		Same as RHS
	BED CONFIGURATION		Same as RHS
	CHANNEL DIMENSIONS		Same as RHS
	FLOW-TYPE		Same as RHS
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		Same as RHS
	IN-CHANNEL VEGETATION		Same as RHS
	WOODY DEBRIS		Same as RHS
	ARTIFICIAL FEATURES AND STRUCTURES		Same as RHS
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Same as RHS
	BANK MATERIAL		Same as RHS
	RIPARIAN VEGETATION STRUCTURE		Same as RHS
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Same as RHS
	RIPARIAN VEGETATION WIDTH		Same as RHS
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Same as RHS
	ARTIFICIAL FEATURES AND STRUCTURES		Same as RHS
	LAND USE		Same as RHS
D - FLOODPLAIN	FLUVIAL FORMS		Same as RHS
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		Same as RHS
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	Consistent with RHS
		Water flow	The method calculates a hydrological modification index at the catchment level (HLM)
B - LATERAL CONTINUITY		Lateral hydraulic continuity	Consistent with RHS
		Sediment (and wood) lateral continuity	Consistent with RHS
C - BANK EROSION / STABILITY			Consistent with RHS
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE

	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	Consistent with RHS + value assigned to artificial channel material (in the RHM)
5. APPLICATION TO WFD		
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)		The method has been developed to comply with WFD requirement. It is the national methodology
APPLICATION TO ALL WATER BODIES		It has been developed in Alpine hydro-ecoregion in Slovenia (26 river types), but it can be applied to all water bodies
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES		It can be used in the classification of any river status
USED TO PREDICT RISK OF DETERIORATION		It can be used to determine the risk of deterioration on macrobenthos
USED TO IDENTIFY IMPROVEMENT TARGETS		Potentially it could be used for this purpose on macrobenthos
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS		It has been used to determine the relationship between the hydrmorphological status and the macrobenthos community
KEY STRENGTHS FOR RIVER MANAGEMENT		Assessment is calibrated to macrobenthos community; it assesses the overall hydromorphological state

Appendix E 20 – IHF (Spain)

1 - METHOD BACKGROUND			
NAME OR CODE			**IHF - Índice de hábitat fluvial (IHF) - Index for the assessment of fluvial habitat in Mediterranean rivers**
COUNTRY			Spain
KEY REFERENCE			Pardo et al. (2002)
WEBPAGE			
CATEGORY			The method aims to characterize physical habitats (heterogeneity) and relate them to biological indicators
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	Remote data could be used to identify survey reaches
		Field survey	7 components of river habitat are assessed in the field: Substrate embeddedness or sediments in pools, rapid frequency, substrate composition, velocity/depth conditions, % of shading, Heterogeneity components, in-channel vegetation cover
		Rapid field assessment	The method makes use of a rapid field assessment strategy
		Existing database	NOT APPLICABLE
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The method makes only the assessment of representative homogeneous reaches
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	NOT APPLICABLE
		Variable length	Homogenous reaches, long enough to allow for the assessment of the 7 components
	LATERAL SPATIAL SCALE	Channel	Assessment focuses on channel
		Banks/Riparian zones	NOT APPLICABLE
		Floodplain	NOT APPLICABLE
C - TEMPORAL SCALE		Physical and morphological assessment	The method considers only the present state
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	It could be used for characterizing river reaches attending to the 7 described components
		Assessment by index	The index is obtained by the sum of single scores for the 7 components. The index does not necessarily evaluate the quality of physical habitats, but rather is a characterization of complexity
		Deviation from reference	NOT APPLICABLE
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	NOT APPLICABLE
		Links with other systems	It is often used in combination to QBR; it can be successfully used in combination to biological indices to allow for the determination of ecological status especially in Mediterranean rivers. It has been included in the HIDRI protocol as tool for the physical characterization of Mediterranean rivers
E - REFERENCE CONDITIONS			Conditions before the impacts occurred, defined by expert judgment and field analysis verification
F - GENERAL INFORMATION	RIVER TYPOLOGY		NOT AVAILABLE
	TYPOLOGY LIMITATIONS		The protocol applies only to Mediterranean rivers (temporary streams are included)
	TYPE-SPECIFIC (Protocol / Assessment method)		The protocol applies only to Mediterranean rivers
	BASIS FOR STANDARDS / THRESHOLDS		Thresholds for the score of reference sites have been calculated as the 25 percentile of IHF values of best reference sites (to divide reference and non-reference sites). Thresholds/scores for 7 components have been determined during the GUADALMED project (2000-2001), by 465 samples (reaches) collected at 156 locations (rivers)
	REACH SCALE SURVEY STRATEGY		The entire selected reach is assessed, but considering 7 component separately (and each component involves a specific spatial extent)
	TIMING AND FREQUENCY		NOT APPLICABLE
	DATA PRESENTATION (OUTPUT/LAYOUT)		Scores for 7 components and a final score
	METHOD SUPPORT / APPLICATION TOOLS		A paper which explain the development of the method and its relationship with biological indicators and indices; a field sheet (Munné et al., 2006 also describe the IHF protocol)

	SPATIAL COMPARISON		The method allows for spatial comparison of physical habitat heterogeneity between Mediterranean rivers, during the same hydrological conditions (it is sensible to hydrological temporal variation)
	CONNECTION TO ECOLOGY		The index relates well to biological indicators and indices (e.g. number of families of macrobenthos, macrobenthos quality index, etc.) and is sensible to the temporal variation of habitat heterogeneity; it characterizes the % of shading
	USERS		The method is widely used by Water Agencies
	SCALE INFORMATION		Only local scale information is provided
	NUMBER OF END PARAMETERS		7 components and 16 distinct parameters
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	Estimation of River velocity/depth conditions
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE
	CHANNEL FORMS		NOT APPLICABLE
	BED CONFIGURATION		Frequency of rapids; heterogeneity components (Natural dams)
	CHANNEL DIMENSIONS		NOT APPLICABLE
	FLOW-TYPE		Velocity/depth conditions (4 categories)
	PHYSICAL / HYDRAULIC VARIABLES		Estimation of river velocity/depth
	SUBSTRATE		Substrate embeddedness or sediments in pools; Substrate composition; Heterogeneity components (leaf litter)
	IN-CHANNEL VEGETATION		In-channel vegetation cover (3 categories)
	WOODY DEBRIS		Heterogeneity components (presence of branches and wood in the stream)
	ARTIFICIAL FEATURES AND STRUCTURES		NOT APPLICABLE
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		NOT APPLICABLE
	BANK MATERIAL		NOT APPLICABLE
	RIPARIAN VEGETATION STRUCTURE		NOT APPLICABLE
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		NOT APPLICABLE
	RIPARIAN VEGETATION WIDTH		NOT APPLICABLE
	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS		Heterogeneity components (Tree roots in the banks); % of shading
	ARTIFICIAL FEATURES AND STRUCTURES		NOT APPLICABLE
	LAND USE		NOT APPLICABLE
D - FLOODPLAIN	FLUVIAL FORMS		NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES		NOT APPLICABLE
	LAND USE		NOT APPLICABLE
4. RIVER PROCESSES			
A - LONGITUDINAL CONTINUITY		Sediment and wood	NOT APPLICABLE
		Water flow	NOT APPLICABLE
B - LATERAL CONTINUITY		Lateral hydraulic continuity	NOT APPLICABLE
		Sediment (and wood) lateral continuity	NOT APPLICABLE
C - BANK EROSION / STABILITY			NOT APPLICABLE
E - CHANNEL ADJUSTMENTS		Planimetric (pattern & width)	NOT APPLICABLE
		Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY		Groundwater connection	NOT APPLICABLE
5. APPLICATION TO WFD			
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)			The method is widely used by Water Agencies in Spain
APPLICATION TO ALL WATER BODIES			It applies to all Mediterranean rivers (Mediterranean regime)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES			The method is considered as complementary to establish reference conditions of high ecological status for biota (because it relates well to biological indices and indicators of ecological quality)
USED TO PREDICT RISK OF DETERIORATION			Flow-related components of the index are sensible to water level temporal (seasonal) fluctuations, therefore it could be used to predict the risk of regime flow alteration, as well as consequence of water pollution (especially during low flow)
USED TO IDENTIFY IMPROVEMENT TARGETS			It could be potentially used for this purpose
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS			It relates well to biological indicators and indices, and it is

	sensible to the temporal variation of habitat heterogeneity, therefore it can be used to identify causes of ecological impacts
KEY STRENGTHS FOR RIVER MANAGEMENT	Meaningful and wide protocol; it collects information from all the river areas and several points of view (hydrological, physical habitat, morphological, etc.)

Appendix E 21 – QBR (Spain)

1 - METHOD BACKGROUND			
NAME OR CODE			**QBR - Índice de vegetación de ribera/ Qualitat del Bosc de Ribera - Riparian Forest Quality Index**
COUNTRY			Spain
KEY REFERENCE			Munné & Prat (1998); Munné et al. (2003)
WEBPAGE			
CATEGORY			The method aims to assess the riparian forest quality
2 - METHOD CHARACTERISTICS			
A - SOURCE OF INFORMATION / DATA COLLECTION		Maps/Remote sensing	It could be applied from aerial photographs
		Field survey	Identification of the bankfull zone (separated in main channel and riparian area) and assessment of the main sections separately for the channel and the riparian area (4 sections: total vegetation cover, cover structure, cover quality, channel alteration); an exhaustive survey of sampling stations is needed to attribute/adjust additional criteria to scores. An additional assessment in 3 sections (slope and form of the riparian zone, presence of islands, presence of hard substrate) is applied to determine river type (headwater, headwater/midland, lowland) and to be applied to section 3 of the QBR
		Rapid field assessment	It is easy and rapid for trained surveyors (it needs knowledge of native/non-native species of riparian vegetation in the study area)
		Existing database	NOT APPLICABLE
		Modelling	NOT APPLICABLE
B - SPATIAL SCALE	HIERACHICAL SPATIAL SCALE	River catchment/Water body/ Reach/Cross Section	The analysis is at the reach scale; if longer river stretches must be assessed, they must be 100 m long
	LONGITUDINAL SPATIAL SCALE	Fixed length	NOT APPLICABLE
		Scaled to channel width	NOT APPLICABLE
		Variable length	Scaled to river type, depending on location (50 m in headwater reaches, 100 m in middle, lower reaches)
	LATERAL SPATIAL SCALE	Channel	The method focuses only on the channel zone between the permanently flowing reach and the bankfull state (emerged areas)
		Banks/Riparian zones	All the riparian zone (in absence of human impact) is assessed or a 50 m wide strip in highly modified floodplains (agriculture, plantations); both river sides
		Floodplain	It considers lateral connectivity between riparian area and floodplain (land use) as well as fluvial terraces modifications
C - TEMPORAL SCALE		Physical and morphological assessment	It focuses on the present state
		Hydrological assessment	NOT APPLICABLE
D - TYPE OF METHOD		Characterization/classification	NOT APPLICABLE
		Assessment by index	The QBR is obtained from the assessment of the 4 sections: to each section, a scale of 4 scores is used (0, 5, 10, 25); additional criteria are considered to adjust the scores. In any case, the min and max scores for each section are 0 and 25 respectively, because an equal weight is attributed to each section. The QBR index is the sum of 4 scores (the total max possible = 100). An additional assessment (to define river type) is accomplished only to help in determining the cover quality of QBR (section 3). The score is converted into five quality classes of riparian habitat
		Deviation from reference	NOT APPLICABLE
		General assessment / Design framework	NOT APPLICABLE
		Modelling status / Scenario	NOT APPLICABLE
		Final expert judgment	The scores for additional criteria have been defined by the expert judgment of the authors according to the importance of each criterion for the studied stream type
		Links with other systems	The method can be used with other metrics to obtain a measure of integrated quality value in streams. It is often used in conjunction with the IHF; it has been included in the HIDRI protocol for the assessment of the riparian forest
E - REFERENCE CONDITIONS			They correspond to the absence of human impact, but the method does not directly refers to reference conditions
F - GENERAL INFORMATION	RIVER TYPOLOGY		River types (headwaters, headwaters/midlands, lowlands) are defined using bank profile (slope and form of the riparian zone), the presence of islands, and the presence of rock substrate

	TYPOLOGY LIMITATIONS		It cannot be applied where riparian vegetation is lacking (e.g. high mountains above the tree line)
	TYPE-SPECIFIC (Protocol / Assessment method)		Only Cover quality (section 3) is calculated considering river types (headwater, headwater/midland, lowland). Following the authors, the use of quality classes boundaries should be checked for other geographical areas
	BASIS FOR STANDARDS / THRESHOLDS		Scores for each section and for additional elements have been defined after trials in four Mediterranean stream catchments in Catalonia (72 sampling sites), and by expert judgment of the authors. Class boundaries have been defined according to the authors' experience: <25 = bad quality, 30–50 = poor quality, 55–70 = fair quality, 5-90 = good quality, >95 = natural conditions
	REACH SCALE SURVEY STRATEGY		All the surveyed reach is assessed, as well as all the riparian strip (laterally); in highly modified floodplains, a 50 m strip is assessed
	TIMING AND FREQUENCY		The analysis of a site takes between 10 and 20 min depending on the experience of the surveyor
	DATA PRESENTATION (OUTPUT/LAYOUT)		Compiled filed sheets, final index, maps showing the QBR quality classes
	METHOD SUPPORT / APPLICATION TOOLS		Two-sided sheet, 2 papers describing its development and functioning
	SPATIAL COMPARISON		It allows for comparison between almost all river types (Munné et al., 2003 demonstrated that it is independent of regional differences in riparian plant community types and also it considers geomorphology of the river)
	CONNECTION TO ECOLOGY		The method informs on the availability and quality of habitats for riparian and terrestrial organisms (connectivity with the floodplain, structure diversity, etc.)
	USERS		User must be familiar with the most common tree and shrub species found in the study areas
	SCALE INFORMATION		Only local scale information (floodplain, reach) is provided
	NUMBER OF END PARAMETERS		To calculate the QBR: 4 main sections, organised into 16 features. To obtain river type: 3 main sections/parameters
3. RECORDED FEATURES			
A - CATCHMENT / VALLEY	LARGE SCALE CHARACTERISTICS		NOT APPLICABLE
	HYDROLOGICAL REGIME	Hydrological conditions	NOT APPLICABLE
		Metrics of hydrological regime	NOT APPLICABLE
		Hydro-peaking	NOT APPLICABLE
	VALLEY FORM / FEATURES		NOT APPLICABLE
B - CHANNEL	CHANNEL PATTERN / PLANFORM		NOT APPLICABLE
	CHANNEL FORMS		Assessment of vegetation on islands (cover, structure, quality). Width of all the islands > or < 5 m is assessed to determine river type (and help the assessment of cover quality)
	BED CONFIGURATION		NOT APPLICABLE
	CHANNEL DIMENSIONS		NOT APPLICABLE
	FLOW-TYPE		NOT APPLICABLE
	PHYSICAL / HYDRAULIC VARIABLES		NOT APPLICABLE
	SUBSTRATE		% hard substrata (negative for tree plant establishment) is assessed to determine river type (and help the assessment of cover quality)
	IN-CHANNEL VEGETATION		NOT APPLICABLE
	WOODY DEBRIS		NOT APPLICABLE
	ARTIFICIAL FEATURES AND STRUCTURES		Rigid structures in the riverbed and Transverse structures in the channel are assessed as additional elements (to adjust score)
C - RIVER BANKS/ RIPARIAN ZONE	BANK PROFILE / SHAPE		Bank profile (score for each bank) is assessed to determine river type (and help the assessment of cover quality)
	BANK MATERIAL		% hard substrata (negative for tree plant establishment) is assessed to determine river type (and help the assessment of cover quality)
	RIPARIAN VEGETATION STRUCTURE		Section cover structure: % of tree and shrub cover, adjusted by the presence of helophytes + longitudinal continuity
	LONGITUDINAL CONTINUITY OF RIPARIAN VEGETATION		Longitudinal continuity is assessed as additional element (to adjust score of cover structure)
	RIPARIAN VEGETATION WIDTH		It is assessed through the total riparian cover in the riparian area (section 1), and adjusted by the degree of lateral connectivity with the floodplain

	VEGETATION COMPOSITION, COVERAGE AND OTHER RIPARIAN VEGETATION CHARACTERISTICS	Cover quality is assessed separately for each river type (presence and number of native tree species); its score is positively adjusted depending on the tree continuity and cover, on the number of shrub species and if riparian zone is structured in gallery; the score is negatively adjusted if there are human buildings, non-native species and garbage
	ARTIFICIAL FEATURES AND STRUCTURES	Channel alteration section: rigid structures on margins, channelized river. Cover quality section: the presence of human buildings is used to adjust the score
	LAND USE	It is assessed through the total riparian cover in the riparian area and the connectivity between riparian area and floodplain woodland
D - FLOODPLAIN	FLUVIAL FORMS	NOT APPLICABLE
	INFO ON FLOODPLAIN FEATURES	NOT APPLICABLE
	LAND USE	Channel alteration section: fluvial terraces modified and constraining the river. Connectivity between the riparian area and floodplain woodland is used to adjust the score of the total riparian cover

4. RIVER PROCESSES		
A - LONGITUDINAL CONTINUITY	Sediment and wood Water flow	The presence of transverse structures influences the score of channel alteration
B - LATERAL CONTINUITY	Lateral hydraulic continuity	It assesses the degree of alteration of river channel (longitudinal structures, terrace modifications)
	Sediment (and wood) lateral continuity	The method considers the connectivity between the riparian area and the woodland in the floodplain
C - BANK EROSION / STABILITY		NOT APPLICABLE
E - CHANNEL ADJUSTMENTS	Planimetric (pattern & width)	NOT APPLICABLE
	Vertical	NOT APPLICABLE
F - VERTICAL CONTINUITY	Groundwater connection	NOT APPLICABLE

5. APPLICATION TO WFD	
OFFICIAL METHOD (WFD implementation) / COMMONLY USED METHOD (not compulsory)	The method is widely used by Water Agencies in Spain and comply with WFD requirement, at least concerning riparian habitats
APPLICATION TO ALL WATER BODIES	In theory the method can be applied to all vegetated rivers (because it does not consider species and it takes into account river type)
USED IN THE CLASSIFICATION OF HIGH-STATUS / OTHER STATUS CLASSES	It could be used together with any other index of water quality to assess the ecological status (all classes) of streams and rivers. It may be a useful tool for defining ‘high ecological status’ under the WFD
USED TO PREDICT RISK OF DETERIORATION	It may be potentially used for this purpose
USED TO IDENTIFY IMPROVEMENT TARGETS	The method may be useful for local managers and for restoration targets
USED TO HELP IDENTIFY CAUSE OF ECOLOGICAL IMPACTS	It may be potentially used for this purpose, although it is addressed to assess actual structure of riparian vegetation
KEY STRENGTHS FOR RIVER MANAGEMENT	It is a tool to provide managers with a simple and very quick method to evaluate riparian vegetation conditions, with potential application from aerial photographs for monitoring purposes