Current Practices on the Water Frame Directive implementation in Spain: Problems and Perspectives

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ABSTRACT: River typologies and methods for selecting reference sites and reference conditions are being discussed in Spain, starting from a single-scale, taxonomic classification of rivers and a relative experience on the use of biotic indexes for water quality monitoring.

The present reductionistic tendency of using the biotic indexes for defining biological reference conditions is discussed, attending to the loosing of basic biological information and precision that occurs when the species composition list and abundance structure are expressed in single numbers.

Ideas for alternative methods are presented, including a hierarchical, multiple-scale river classification scheme, from which selection of reference sites can be made, according to the status of hydromorphological and water quality elements. The importance of achieving the finest taxonomic resolution of the biological data for defining the reference conditions is remarked, in order to establish a solid, scientifically based pool of data from which the ecological status of rivers can be precisely estimated, preserving the peculiarities of each river type.

INTRODUCTION

The Water Frame Directive represents and environmentally advanced and integrated water management approach, promoting the collaboration of multiple disciplines and the participation of the scientists and the rest of the public in the management processes.

The traditional perception of the river as a source of hydric renewable resources, power and transport facilities is intended to be replaced by the idea of the river as an ecosystem, whose ecological status has to be preserved in biological, hydromorphological and physico-chemical terms, according to their natural conditions. This implies that previous methods of river monitoring based on water quality should be complemented by alternative systems that convey geomorphological and biological information, in order to assess the ecological river functioning and define restoration programs promoting river naturalness, as it has been proposed by Petts *et al.* (1992) and Frissell & Ralph (1998).

In the implementation of the WFD, river typologies and classification have to be developed for many pourposes; first, to describe physical characteristics for comparison and evaluation of changes in response to human impacts or natural disturbance from reference conditions, and secondly, to determine the suitability of restoration procedures according to the stream channel types, taking into account that they have to be consistent with the natural hydraulic and geomorphic conditions of the different reach types (Gordon *et al*., 1992; Jungwirth *et al*., 2002).

Until now, different river typologies have been proposed, which differ not only in the variables and criteria but also on the river characterization approach and nomenclature, making difficult the comparison of the results and the transferability of suitable restoration procedures (i.e. Wasson *et al*, 2002; Munné & Prat, 2004, etc).

The description of the reference conditions is an important task within the WFD to evaluate the ecological status of the water bodies, which should be determined on the basis of the relevant biological, hydromorphological and physicochemical elements.

Although the classification of the ecological status is to be based on these quality elements and not in parameters (REFCOND, 2003), several biological indexes have been proposed for evaluating reference conditions and ecological status of rivers in Spain (Bonada *et al*., 2002, Alba-Tercedor *et al*., 2002; Munné *et al.,* 2003), with strong limitations do the fixed and encapsulated information offered by their numerical values.

In this paper, the possibility of developping a commun hierarchical, multiple-scale river classification approach for the European Basins is discussed, together with the current reductionistic tendency of using biotic indexes for defining biological reference conditions in the context of the WFD.

Our comments try to reinforce the strength and limitations of these indexes for establishing reference conditions, advocating for a more taxonomically precise ways of defining the biological communities, and promoting the use of "similarity indexes" to evaluate the ecological status or rivers, in terms of the "distance" from the species composition and structure of the original communities.

The interest of developing geomorphological and hydrological reference conditions and methods to evaluate riparian conditions is also discussed, having a large scientific information for biological and physico-chemical ecological status criteria and variables, but a significant much less documentation and experience on hydromorphological quantitative characteristics and evaluation.

RIVER TYPOLOGIES IN THE CONTEXT OF THE WATER FRAME DIRECTIVE

The WFD promotes the classification of rivers as one of the first tasks to be undergone by the State membres for establishing reference conditions.

Two classification systems, A and B, are proposed in the official text of the Directive. System A takes into account the Limnofauna Europaea biogeographic regions identified by Illies & Botosaneanu (1963) and the altitude, size and geology classes of the catchment area, attending a regional scale, whereas system B suggests alternative variables, some of them corresponding to a larger, fluvial segment or channel reach scale, as distance from river source, mean water width, depth, slope, etc.

Within this open approach, different classification approaches have been followed by the different countries, making difficult the comparison of the results, as different characterization attributes have been used in each case, and also different nomenclatures have been selected for identifying the river types.

In the Southwest of Europe, Wasson *et al* (2002) have differentiated 22 hydroecoregions for identifying the French river types, considering differences on climate, geomorphology and geology, whereas 32 Spanish river types have been obtained by automatic clustering using different variables and different range of values (CEDEX, 2005), which can not be easily compared among each other, neither with the 16 Portuguese river types characterized by biotic and abiotic factors (Alves *et al*., 2005) or with the fluvial regions and subregions identified in Catalonia (ACA, 2002).

In this European western mediterranean area, probably some commun river types exist in the mentioned countries, but the established river typologies do not facilitate the transfer of information and experience, and the occurence of sites with high ecological status that can be available in some areas for establishing reference conditions, can not be used in other areas with river types ecologicaly equivalent.

A commun european river classification framework should be very useful to avoid these country-scale typologies and nomenclatures, and to achieve an integrated, physically-based approach under which ecological information and experience could be easily transferred. This could be useful not only for the ecological status evaluation, but also for the proposal of restoration activities, monitoring and river conservation measures.

In this context, the hierarchical, multiple-scale framework proposed by many authors for regionalization the landscape and characterization the drainage network (Frissell *et al.*, 1986; Richards *et al*., 2002; Benda *et al.*, 2004) seems to be the most appropiated, having being suggested by the Spanish rivers by González del Tánago & García de Jalón (2004).

A first ecoregion scale division could be considered for the European Basins, integrating the characteristics of climate, geology and potential vegetation which can be related to aquatic ecosystems functioning (Bayley, 2004; Stoddard, 2004), following a similar approach to that of Rivas Martínez *et al*. (2002) used for the Iberian peninsula, or Rodweel *et al.* (1997) used in the European Habitat Directive.

After recognizing the ecoregion level, catchment area attributes of each fluvial segment, identified as the fluvial length between tributary confluences according to Benda *et al.* (2004) can be characterized, in terms of size and geology, using the same classes proposed by the WFD.

Morphological and flow regime characterization could be applied at the fluvial segment scale, following similar concepts and methodologies suggested by Montgomery & Buffington (1993) and Poff & Ward (1989) respectively, and finally, bed material, roughness elements, water velocity, etc., can be used to characterize the channel geomorphic units, according to Hawkins *et al*. (1993) and Bisson & Montgomery (1996).

Within this hierarchical multiple-scale fluvial habitat characterization, river types and reference conditions for each river type could be defined at different levels, depending on the target biological communities, considering that meso-scale (fluvial segment) could be enough for fish reference conditions, whereas a larger, channel geomorphic unit scale, should be considered for macroinvertebrates.

An implementation of this hierarchical river characterization squeme has been done in the Guadiana Basin, Spain (see Table I, González del Tánago *et al*., 2004), facilitating the river classification at fluvial segment scale and the macroinvertebrate communities description at geomorphic unit scale, and a similar approach could be valid for the rest of the European Basins, facilitating the interpretation of the results and the information transfer.

IMPORTANCE OF SPECIES IDENTIFICATION FOR ESTABLISHING RFERENCE CONDITIONS AND ASSESSING THE ECOLOGICAL STATUS

The importance of species identification was pointed out some time ago by Resh & Unzicker (1975) and García de Jalón *et al.* (1981), preventing from the mistakes and lack of accuracy in the use of water bio-indicators without the adequate precision of taxonomic determination.

Compin & Céréghino (2003) have found in French rivers that by using the species level of taxonomic resolution, the species richness was sensitive even to slight disturbances in highly diversity mountain streams. In Ireland, Bradley *et al* (2005) were able to identify type-specific macroinvertebrate assemblages of reference conditions for four river types, by means of using species-level indicators (determinated to the lowest possible taxa using standard taxonomic keys).

These ideas are nowadays relevant in the context of the WFD defining reference conditions for biological communities, taking into account that the sensibility of different organisms to different human pressures may greatly vary from one species to another, even among the species in the same genus, and with greater emphasis among species belonging to the same family.

This is especially true for those genus or families with a broad ecological spectrum that include many species, which often are community dominants, like *Baetis* and *Hydropsyche*. As an example *H. exocellata* and *B. rhodani* are well known tolerant species to eutrophication and organic pollution, while on the contrary *H. tibialis* and *B muticus* are sensible species to that pollution.

These different species can play a different synecological role in the functioning of their respective communities of reference. Even though, in the cases of vicariant species with the same ecological roles (feeding mechanisms, reproduction strategy,..), their speciation procceses have push them to evolve and be adapted to different physical habitat conditioning (different optimal temperature metabolical rates, different velocity resistance,..).

Therefore, the use of indicator organisms identified at species level is much more precise than using them at genus or even worse at family level. The effort and the resources needed to achieve species level identification are much greater than those needed to determine broader taxa, but we think that this increase in effort is widely justified. Reference conditions are the foundation on which river monitoring and restoration procedures are intended to be based, being also valid for detecting aquatic ecosystems at risk and endangered populations (Reece & Richardson, 2000).

BIOLOGICAL INDEXES IN THE CONTEXT OF THE WFD

The application of the WFD has promote the appearance of numerous types of 'indices' (biotic, health, integrity, metrics,..) for different quality elements in each State member, but it is important, prior to their use generalization, to evaluate the spatial, temporal and biological limitations of these indices.

Townsend & Riley (1999) have pointed out the absence of concordance between any single index of health and several fundamental features of fluvial ecosystem functioning. The indicator capacity of biological communities is encapsulated in biotic indices that often do not reflect the spatial and temporal variation of many types of disturbances.

Although the WFD states clearly which variables should be used as biological quality elements, such as the Communities composition, Population Abundance and the presence of Sensitive Taxa to the impacts characteristic for the stream type, several biotic indexes have been proposed in Spain to evaluate the ecological status of rivers, by means of comparing the currrent score value obtained from the present communities with the score value adopted as corresponding to the "good ecological status" (Alba *et al*., 2002).

The biological-indicator concept included in the biotic indexes has been very useful for summarizing general conditions of water quality in running waters, and it has been easily understood by civil engineers and technical staff in charge of river management without any ecological or biological knowledge. But these indices oversimplify the survey results, as they are obtained by adding the 'weight factor' associated to each species present in the community, which is given on subjective assessments about the species tolerance or sensitivity to organic pollution.

Other pollution types are not so simple to detect and often are disguised by organic pollution. In a scientific based analysis of biological indicator value of different aquatic species, laboratory ecotoxicological studies are needed in order to asses their sensibility to different toxicants. Camargo *et al*. (1992) studied the sublethal effects of fluoride on different Spanish species of net-spinning cadis-flies, and they found out that the relative resistance of the species to this pollutant was different than that to organic pollution.

Valuable laboratory experiments have been conducted with non-target macroinvertebrates to assess the toxicity of fluoride (Camargo *et al*., 1992; Camargo, 2004), ammonia (Alonso & Camargo, 2004), nitrate (Camargo *et al*., 2005), chlorine (Camargo, 1991), and water acidification (Camargo, 1995), but little efforts have been done to incorporate this knowledge to the use of biotic indices.

Also, we must be conscious that under different pollution types or different pressures, the same species may be tolerant to ones and sensible to others. Most Plecoptera species are well known to be sensible to organic pollution, whereas they are tolerant to heavy metals (Rosenberg & Resh, 1993; Wetzel, 2001) and acidification, like *Leuctra hippopus* and *Amphinemura sulcicollis* (Weiderholm, 1984).

The use of multiple lines of evidence from field and laboratory data to assess the occurrence or absence of ecological impairment in the aquatic environment has been successfully shown by Hall & Giddingsb (2000). Benthic and fish Integrity indices give conflicting results when assessing biological impact in a Maryland river due to the differences in exposure among habitats occupied by these different taxonomic assemblages, and only when data from different species toxicity test were used, the impact mechanisms were understood.

But other impact types than pollution, like flow regulation or stream canalization, are very frequent in the rivers, and their effects can take place at different spatial and temporal scale than those from organic pollution. The effects of flow regulation, together with those of canalization have been studied in some Spanish rivers (Garcia de Jalón *et al*, 1992; Sainz de los Terreros, 2003). It is clear that the sensibility to these impacts differs for each taxa and for their sensibility to organic pollution. Often intolerant species to organic pollution are tolerant to stream regulation.

Predator species are frequently common below dams (Ward & Stanford, 1979; Petts, 1986). Predaceous Plecoptera are found below oligotrophic reservoirs with aerated outlets, being these stone flies well known intolerant species to organic pollution.

One should conclude that the traditional biotic indexes based on the tolerance of taxa to organic pollution have strong limitations for assessing the ecological status of rivers in the context of the WFD, and that other river pressures have to be evaluated at different temporal and spatial scales of the biological response.

Finally, the WFD promotes the recovery of the original, pristine communites prior to human disturbance, and the biological assessment has to be emphasized on if all the relevant species that should be in the river are in fact there, and how much the present community differs from the original one or defined as the reference.

In this situation, a more precise taxonomic identification of river fauna and flora than that required by the biotic indexes (genus or family level) is necessary, and a comparative study of the present situation in relation to the reference condition seems to be demanded, without any previous consideration of the species as indicators of water quality, neither of the scoring system of prescribed values of good and bad conditions, like those reflected in the traditional biological indicator based indexes.

INTEREST OF SIMILARITY INDEXES IN THE CONTEXT OF THE WFDA

Similarity indexes were proposed by Hellawell (1986) to be used on stream bio-monitoring, especially for aquatic organisms, and more recently Winward (2000) has suggested their use for monitoring vegetation resources in riparian areas. Similarity indexes can be very useful for quantitative comparison of present vs. reference conditions, by means of identifying key species and comparing their abundance and space and time distribution in present conditions with those considered as “natural”.

Similarity indexes that mathematically fluctuate between zero and one are the most interesting for the WFDA (see Table II). They can use qualitative data (presence/absence of species like those used by Jaccard, Sorensen, etc.), or quantitative data (relative abundance of species as proposed by Raabe, or absolute abundance as propose in Czenowski index). Therefore, in order to asses the status of the community composition, qualitative similarity index for comparing to reference composition can be very appropriated, while assessing abundance status quantitative similarity index can be used.

Also, these similarity indexes may be used directly as the EQR 'ecological quality ratio' for each metric, as the index value for the reference conditions is always one (identity), and the value of the index would be directly the EQR. Furthermore, if there are different reference sites for the same river type, the issue of determining thresholds between "very good" and "good" ecological status may be undertaken using the minimum value of similarity between two communities from these reference sites.

GEOMORPHOLOGICAL AND HYDROLOGICAL INFORMATION OF REFERENCE CONDITIONS

Much of the effort that has been done until now in the implementation of the WFD has corresponded to biologists and ecologists working in different flora and fauna groups, but very few contributions have appeared from geomorphologists or hydrologists trying to define more precisely the hydromorphological conditions mentioned in the WFD, mainly based on flow regime and riparian structure.

Many attempts have been done to characterize the natural flow regime conditions (see Olden & Poff, 2003), considering the importance of protecting and restoring the river´s natural flow variability to sutain and conserve native species diversity and ecological river integrity (Poff *et al.*, 1997). Magnitude and duration of average flows, magnitude, duration, frequency and timing of extreme flows, predictibility and flow change ratio are selected by Richter *et al.* (1997) as hydrological parameters with significant biological meaning, which can be relatively easy evaluated and quantified in most of the cases and compared with the values corresponding to natural flow regimes. This comparison can be also be quantified using quantitative similarity indices, specially the Czenowsky index which use absolute values.

Baeza & García de Jalón (2004) have measured the alteration of natural flow regime by five Ebro Basin reservoirs using Richter *et al.* (1997) parameters, comparing stream-flows in pre-regulation and post-regulations conditions. Accepting natural pre-impoundment flows as reference conditions, regulated flows are evaluated using similarity indices, analysing the magnitude of the alterations and their frequency. The magnitude needs to fix a threshold of dissimilarity (that depends on natural variability of flows) and the frequency measures the number of times a parameter exceeds the threshold.

Finally, the riparian conditions should be assessed not only on the basis of the composition and structure of present vegetation, as some curently used indices do (i.e. QBR, Munné *et al.*, 2003) but also taking into account critical factors for achieving sustainable riverlandscape dynamics, as lateral connectivity, woody species age diversity, sediment availability, etc. (Richards *et al*., 2002; Hughes, 2003).

The challenge for the hydromorphological assessment in the context of the Water Frame Directive probably lies on selecting the appropriate spatio-temporal scales of appraisal characteristics and effects from human disturbances, which could be quite different from those to assess the present biological status, and much more complicated and fuzzy than them, taking into account the trans-scale processes that link physical structures and biological communities in fluvial ecosystems (Montgomery, 1999; Poole, 2002).

CONCLUSIONS

After discussing several initial tasks for implementing the Water Frame Directive, we should conclude that their development represents an historical, scientifically-based opportunity to document the European river types; to evaluate their ecological status and to propose commun river restoration strategies, delineating a further field-laboratory exercise of monitoring and testing hypothesis and theories of river responses and recovery processes from human disturbances.

A commun hierarchical riverlandscape ecosystems characterization and classification for the European Basins is proposed, in order to facilitate the transferability of data and experience among the State members, taking profit from the commun effort wich has been done until now.

The importance of acquiring the biological information at the more precise, possible taxonomical level is argumented, considering the different tolerance of species within the same genus or family to the different human pressures.

The traditional biotic indexes used for monitoring water quality related to organic pollution seem to be very inapropriated for establishing reference conditions and assessing the ecological status of the rivers, as well as other indexes that simplify the composition and abundance of communities in a single, numerical value.

As the WFD promotes the naturalness of the lotic ecosystems, which could mean different composition and structure of the biological communities in the different rivers, the utility of the similarity indices seems to be clear, not only for assesssing the distance of the present communities from the original ones or that considered as a reference, or quantifying the alteration of the flow regimes, but also for projecting ecological targets in the restoration programs and river conservation plans.

Finally, the importance of selecting apropriated reference sites for conservation strategies, and the interest of defining precisely the reference conditions with biological robust basic data are also remarked, representing a very usefull basic information for the future, when better understanding and new perspectives in river ecology can arise, different from those of today.

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Table I.- Hierarchical characterization of fluvial segments in the Guadiana Basin (Spain). The Biogeographic Regions follow the work of Rivas Martínez *et al.* (2002); Integrated geology and catchment area size correspond to the lower limit of the respective fluvial segment, and follow WFD classes; flow regime are characerized according to the main channelflow origin and seasonality; valley type takes into account the influence of the slope hydrology and floodplain processes in the river; channel type follow Rosgen (1996) classification adapted to the Guadiana Basin; the substratum is characterized by the D_{50} bed material: and the fluvial segment correspons to the length of the river between tributary confuences. (González del Tánago *et al*., 2004).

Biogeographic Region	Integrated Geology	Catchment Area Size	Flow Regime	Valley Type	Channel Type	Substratum	Fluvial Segment
Province: Mediterránea Ibérica Occidental Subprovince: Luso-Extremadurense	Siliceous	Large	Permanent, groundwater	4	Cc	Fines+Gravel	Jabalón-3
				4	Cc	Fines+Gravel	Jabalón-2
				4	Cc	Fines+Gravel	Jabalón-4
				4	Cc	Fines+Sand	Jabalón-1
			Permanent, pluvial	2a	C	Sand	Matachel-3
				2b	E	Gravel	Zujar-5
				2b	E	Gravel	Zujar-6
				3	C	Gravel	Gevora-3
				3	C	Gravel	Bullaque-3
				3	E	Gravel	Ruecas-3
				3	E	Gravel	Zujar-8
				3	Ec	Gravel	Matachel-4
				4	Dt	Gravel+Sand	Bullaque-2
			Temporary	2a	Cr	Boulder	Zujar-1
				2a	C	Boulder	Zujar-3
				2a	C	Boulder	Guadamez-1
				2a	C	Gravel	Guadamez-2
				2a	Cr	Sand	Valdeazogues-2
				3	C	Gravel	Zapaton-2

Biogeographic Region	Integrated Geology	Catchment Area Size	Flow Regime	Valley Type	Channel Type	Substratum	Fluvial Segment
Province: Mediterránea Ibérica Central *Subprovince:* Castellana	Clay	Very Large	Permanent groundwater	4	Ec	Fines	Guadiana-5
				4	Ec	Fines	Ciguela-5
				4	Ec	Fines	Ciguela-6
			Permanent, pluvial	3	E	Fines	Guadiana-7
				2b	E	Fines & Sand	Guadiana-6
		Large	Permanent groundwater	4	Cc	Fines	Zancara-4
				4	Cc	Fines	Zancara-6
				4	Cc	Fines	Zancara-3
				4	Cc	Canal	Guadiana-3
			Permanent, pluvial	4	G	Fines	Ciguela-4
				4	G	Fines	Ciguela-3
				4	E	Fines	Ciguela-1
				2b	Cc	Fines	Rus
				4	G	Fines	Riansares

Table II.- Similarity Indices proposed to compare differences between present and reference conditions in the context of the WFD. Qualitative indices use species or taxa presence/absence data, where ‘r’ and ‘p’ are the number of species present in the reference and the present community, and ‘c’ is the number of species in common among both communities. Quantitative indices use species abundance data (number of individuals per specie). Raabe index uses relative abundances data (number of individuals per specie ‘n_i’ divided by total number of individuals in the community ‘N’), while Czekanowsky index uses absolute numbers (number of individuals per specie). Czekanowsky index may also be used to compare hydromorphological conditions using the values of the hydromorphological parameters instead of number of individuals.

- **Qualitative**
  - Jaccard (1912) $\boxed{I = \frac{c}{p+r-c}}$
  - Sorensen (1948) $\boxed{I = \frac{2c}{p+r}}$

$$[p = n^{o}\, sp.P]$$
$$[r = n^{o}\, sp.R]$$
$$[c = n^{o}\, sp.P \cap R]$$

- **Quantitative**
  - Raabe (1952) $\boxed{I = \sum_{i=1}^{i=s} \min(h_{iP}, h_{iR})}$ $\quad [h_{iR} = \frac{n_{iR}}{N_R}]$
  - Czekanowski (1913) $\boxed{I = \frac{2C}{P+R}}$

$$[P = \sum n_{Pi}]$$
$$[R = \sum n_{Ri}]$$
$$[C = \sum \min(n_{Pi}, n_{Ri})]$$