Background paper on hydromorphology

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1. Introduction

The aim of the ECOSTAT Classification workshop with respect to hydromorphology is to facilitate a better common understanding on the use of hydromorphological quality elements for the overall assessment of ecological status and potential. This is part of a wider work item on classification in the ECOSTAT work programme focusing on the linkage between supporting and biological quality elements (BQEs). It also aims to specifically contribute to planned activities outlined in the Terms of Reference of the Ad-hoc Task Group on Hydromorphology[1].

The aims of this workshop are to

- discuss challenges related to indicating hydromorphological pressures by BQE methods (see Section 3 of this paper) and possible good practices already in place in the Member States;
- discuss possible ways of aligning supportive hydromorphological QE assessment with BQE assessment to classify the ecological status (see Section 4 of this paper).

To support these discussions, Figure 1 provides a conceptual scheme that links the hydromorphological pressures to the impacts and ultimately to the ecological status (assessed by the BQEs and supporting hydromorphological and physico-chemical quality elements).

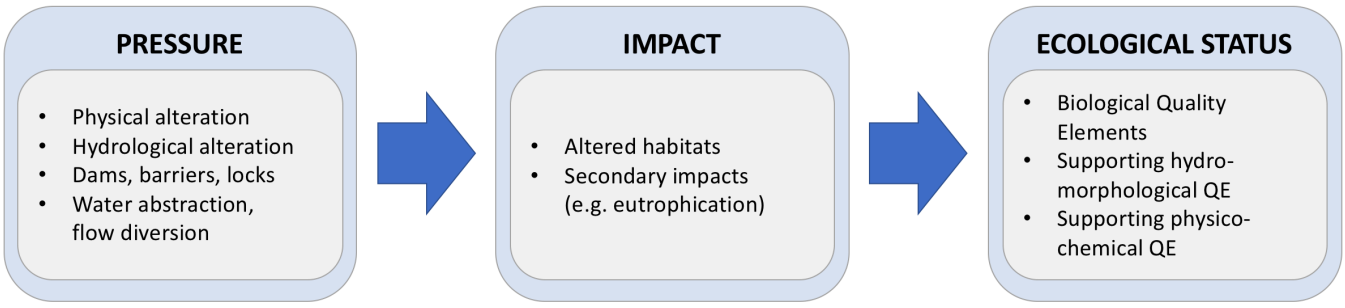


Figure 1: Conceptual scheme linking hydromorphological pressure, impacts and to ecological status classification.

[1] https://circabc.europa.eu/sd/a/8070370f-8935-4407- ab50-b7c0835ead7a/ToR%20Ad-hoc%20hvdromorphology%20FINAL.docx

2. State-of-play

2.1. Hydromorphological pressures & BQE assessment

A first CIS workshop on "Hydromorphology and WFD classification" took place in Oslo (NO) in October 2015. In this workshop, it was concluded that there are many good examples of biological indicators responding to hydromorphological pressures[2]:

- All BQEs may respond but the strength of the response depends on the choice of metrics.
- Fish, macrophytes, macroinvertebrates and (more rarely) diatoms are the biological quality elements most used to detect effects of hydromorphological pressures. Phytoplankton is used in specific cases (impounded rivers and reservoirs).
- Many of the intercalibrated BQE methods are generic multi-metric indices responding weakly to specific hydromorphological pressures because they were not originally designed to be specifically sensitive to such pressures. This can be improved by using more targeted indicators. There are already good examples of Member States using such targeted indicators in their biological assessment systems.
- Hydromorphological pressures affect BQEs through morphological process shaping habitat quality and structure. Riparian vegetation usually plays an important role. There is a need to better characterize and quantify the links between hydromorphological alteration and biological impact using appropriate data and targeted indicators. This requires that spatial and temporal scales of monitoring of BQEs are in line with hydromorphological processes.
- There is a need to quantify hydromorphological pressures and their effects on the biology under a multi-stressor environment in order to separate different causes of the alteration and to design appropriate measures.
- River typologies should reflect natural variability in hydromorphological characteristics and processes. This is crucial because differences in natural hydromorphology result in different reference conditions for the biological quality elements.
- BQE assessments need to be supplemented with information from the supporting elements in order to identify inconsistencies between hydromorphological and biological assessment, to diagnose problems and to identify effective restoration measures. A clear understanding of what is meant by "supportive element", how it should be used, and how it is reported is needed.[3]

According to WISE, for the second cycle RBMPs almost all Member States (with few exceptions) report to have one or more BQE assessment methods in place, which are sensitive to hydrological and/or morphological changes. Such methods have been reported for various BQEs in the different water categories (rivers, lakes, coastal and transitional waters).

At the same time, from the intercalibration technical reports, there is not much evidence that the BQE methods currently in use reliably pick up the effects of hydromorphological alterations. To be sure that hydromorphological pressures and their effects do not remain undetected, it is therefore very important to use hydromorphological classification methods alongside the BQEs.[4]

In 2016-2017, a CIS activity took place collecting information from European countries on hydromorphological assessment methods used for WFD implementation.[5] As part of this exercise, it was concluded that approximately half of the reported methods for hydromorphological assessment (total of 56 methods reported) support the risk analysis or ecological status classifications or both. In the case of

[2] 2015 CIS Workshop conclusions on Hydromorphology and WFD classification.
[3] Ibid.
[4] Van de Bund, W., Poikane, S., Salas Herrero, F., 2018. ECOSTAT discussion paper: European surface water ecological assessment methods – an overview of their sensitivity to pressures. European Commission DG Joint Research Centre.
[5] Kampa, E. & Bussettini, M., 2018. River Hydromorphological Assessment and Monitoring Methodologies. Final report - Part 1: Summary of European country questionnaires.

status classification, a higher number of methods are used to support ecological classification at high status only (practised in 15 European countries) than for classification in all five ecological status classes (practised in eleven European countries). In most countries where hydromorphology is assessed in five classes, it is mainly being used as an element supporting ecological classification and hydromorphological status is used directly to downgrade only from high to good ecological status (see further information in the Annex to this background paper).

Therefore, it has become clear that most countries have developed classification methods for the hydromorphological supporting elements. However, pressure-impact relationships between those methods and the BQEs need to be demonstrated.

At the moment, there are still big gaps on understanding how hydromorphological pressures affect biological communities, mostly because the effects of those pressures on hydromorphological processes and features and the consequent modifications in terms of habitat have not always been considered in hydromorphological and biological methods. Addressing the responses is therefore difficult.

Biological methods are typically focused on specific species/groups and the assessment metrics that are used do not necessarily respond to hydromorphological modifications in a comprehensive way. On the other hand, some Member States' methods assess hydromorphology per se, due to the complexity of responses, the lack of knowledge of certain key linkages between hydromorphology and biology, the complexity of responses, and, above all, to the fact that hydromorphology promotes functionality for river ecosystems (but the established BQE methods do not necessarily address this functionality). Independently from the target, the importance of adopting a sounder and so wider – although more complex – approach for hydromorphological assessment is also highlighted by several Member States[6].

2.2. Hydromorphological assessment

An assessment of hydromorphology is formally required by the WFD in the pressure analysis and the water body status classification. The pressure analysis results into the identification of significant or non-significant hydromorphological pressure. For the water body status classification, the assessment of hydromorphology is only prescribed for classifying the high ecological status (i.e. reference conditions). The good and moderate status classes, however, need to be "*consistent with the achievement of the values specified [...] for the biological quality elements*" (WFD Annex V).

In the earlier discussions on this topic, it was generally acknowledged to perform hydromorphological assessment over the full gradient of anthropogenic degradation, preferably in a resolution that allows for distinguishing between (or even within) BQE status classes. The arguments given were as follows:

- Such a hymo assessment can be used to validate/improve the status classification results gained from BQE assessment (eliminating 'false positives' = biology is good, but hymo impact is present; or 'false negatives' = hymo-sensitive biology is bad, but water quality is the problem).
- It allows for selecting and planning of appropriate mitigation measures at water body level, facilitating prognosis (e.g. via habitat modelling) and monitoring of their success.
- The effect of the specific uses on the hydromorphology, which is relevant for allocating heavily modified or artificial water bodies, can be assessed. This facilitates the hydromorphological characterization of the maximum and good ecological potential, as well as the quantification of the 'distance to target' if the water body fails to meet the good ecological potential.
- In accordance with the 'no-deterioration objective' of the WFD, hydromorphological assessment allows for evaluating possible effects of activities/developments at the water body, with sensitive assessments being capable of indicating within-class changes.

[6] Bussettini, M. & van de Bund, W., 2018. Key conclusions and recommendations. In: Workshop on Methods for River Hydromorphological Assessment and Monitoring, 20-22 November 2017, Madrid. Part 2 – Summary report of workshop – Key conclusions & recommendations. April 2018.

- Floodplains as relevant compartments of river ecosystems, often only indirectly addressed by national BQE methods, can be integrated in ecological status classification.

An assessment covering the full gradient of anthropogenic degradation should refer to type-specific reference conditions established according to WFD prescriptions (i.e. absence or negligible presence of anthropogenic pressures so that processes are not impaired)[7]. On the basis of these prescriptions, Member States have defined such conditions for their hydromorphological methods using a wide variety of approaches (e.g. theoretical, empirical/statistical, historical, and/or expert judgment)[8].

The hydromorphological classification needs to be based on a typology of water bodies that account for the different hydromorphological processes and related feature patterns (i.e. 'hymo-types'; see also next section), sharing the same behavior and character in terms of hydromorphological functions and features (e.g. energy, channel planform morphology, assemblage of geomorphic units).

3. Challenges related to indicating hydromorphological pressures by BQE methods

3.1. BQE sensitivity to hydromorphological pressures

In general, biological indicators integrate different pressure effects (which is their specific asset to provide integrative assessment), with pressure-specific responses being rather the exception than the norm. This integrative character is due to similar 'modes of action' of the different pressures, mainly acting on the same features of the ecological niches, which are in case of hydromorphological pressure: presence and accessibility of habitats (incl. sediment starvation, loss of the hyporheic zone, impairment of species mobility due to hydrological alteration), oxygen depletion (due to stagnation, siltation), scouring at high flows and changes in biotic interactions ('realized niche').

Related questions:

Q1. What are the main challenges in developing biological assessment methods sensitive to hydromorphology?

Q2. Which BQEs are used to assess the effects of hydromorphological pressures, which indicative parameters and bioassessment metrics/features of the biological community are most relevant?

Q3. How was the sensitivity of your BQE method(s) to hydromorphological pressures validated?

Q4. Has your BQE method sensitive to hydromorphology been intercalibrated successfully?

Q5. Is a pressure-specific BQE method for hydromorphology in place in your country? Which specific types of hydromorphological pressures are covered?

3.2. WFD water body typology and biological reference conditions

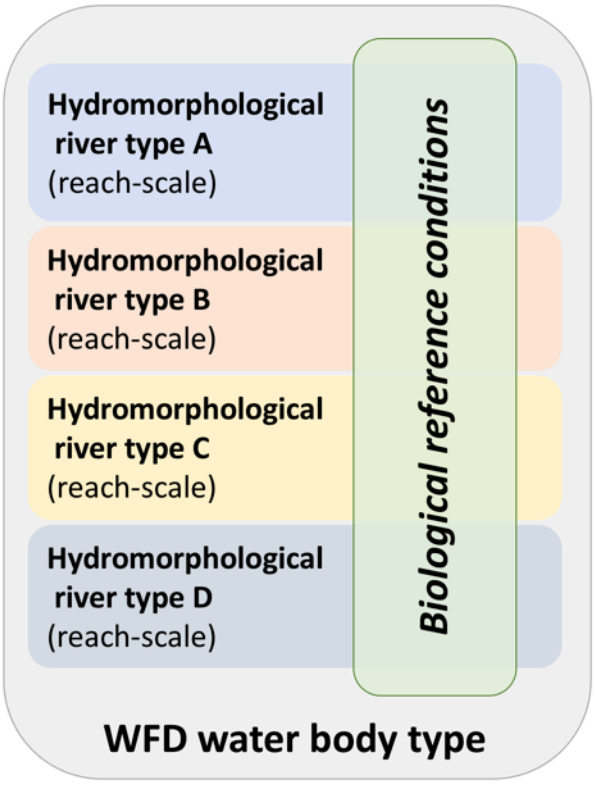
Water body typologies (especially those established according to WFD System A including ecoregion, catchment size, altitude and geology) may not consider relevant hydromorphological factors that distinguish between river reaches featuring homogeneous fluvial processes ('hymo-types'). This results in type delineations that may encompass various (functionally different) hymo-types. This causes within-type variability in the biological reference conditions making such types unsuitable for BQE methods that are sensitive to hydromorphological pressures (Figure 2). In most Member States the development of river typologies and water body delineation took place before hydromorphological characterization methods were developed. Different Member States have used quite disparate criteria (from no or limited consideration of hydromorphology to evaluation of hydromorphology in combination with the other

[7] "There are no, or only very minor, anthropogenic alterations to the values of the physico-chemical and hydromorphological quality elements for the surface water body type from those normally associated with that type under undisturbed conditions. The values of the biological quality elements for the surface water body reflect those normally associated with that type under undisturbed conditions, and show no, or only very minor, evidence of distortion. These are the type-specific conditions and communities." (WFD Annex V)

[8] Bussettini, M. & van de Bund, W., 2018. Key conclusions and recommendations. In: Workshop on Methods for River Hydromorphological Assessment and Monitoring, 20-22 November 2017, Madrid. Part 2 – Summary report of workshop – Key conclusions & recommendations. April 2018.

possible characteristics) that are likely to result in inconsistencies between countries. A uniform coherent approach is necessary to properly take into account hydromorphological conditions.[9]

Strictly adhering to predefined typology factors (e.g. 100-1000 km^2 catchment size as prescribed for 'System A') may even impose artificial type allocations with little resemblance in nature.



Related questions:

Q6. Do you use the same typology for biological and hydromorphological assessment in your country?

If river hydromorphology has not been considered in type-delineation, the type-specific biological reference conditions may cover various hymo-types (see Figure 2), including their spatial and temporal variability. This can result in an overly broad definition of biological reference conditions and may imply limited sensitivity of the BQE method to hydromorphological degradation. In a strict sense, national typologies not considering hydromorphology are inadequate for using BQE methods that are sensitive to hydromorphological pressures.

Related questions:

Q7. Do the biological reference conditions in your country sufficiently consider the biological variability at high status due to different hymo-types within a particular WFD water body type?

Figure 2: Type-specific biological reference conditions covering different hydromorphological river types (depending on national WFD water body type definition).

3.3. Delineation of water bodies and representative monitoring sites

For the reasons given above, the definition of hydromorphologically relevant water body types and related hydromorphological and biological reference conditions represent crucial factors for BQE method sensitivity to hydromorphology. If there are different hymo-types within a single WFD water body type, hydromorphological pressures will have different impacts within a WFD type (due to different hydromorphological processes), with the same pressures altering the physical habitats relevant for the biological communities in different ways. For this reason, it is important to consider hymo-types in the delineation of water bodies and the selection of representative monitoring sites.

Related questions:

Q8.Have biological monitoring sites been selected in consideration of hydromorphological conditions/processes within WFD water body types?

3.4. Morphology, hydrology, continuity

Linking hydromorphology to biology works best on the level of physical habitats (at the scale of geomorphic units/meso-habitats; Gurnell et al. 2016), and good correlations between in-stream and riparian morphology and the biology have frequently been demonstrated (e.g. Lorenz et al. 2004; Baattrup-Pedersen et al. 2005). The link to the hydrological components is less straightforward

[9] Ibid.

(Rosenfeld 2017) but linking the hydrological component to the availability of habitats facilitates this. This also relates to the more dynamic nature of the hydrological compared to the morphological components.

Related questions:

Q9. Which hydromorphological quality elements (morphology, hydrology, continuity) relate to your national BQE methods?

Q10. Are your BQE methods/metrics related to different hydromorphological pressures (e.g. flow reduction, channelization, hydropeaking)?

3.5. Spatio-temporal match

The hydrological regime of a river generally drives hydromorphological dynamics that condition high turnover rate and high spatial heterogeneity of the physical habitats. An ideal assessment of hydromorphological pressure by BQE methods thus requires the monitoring of physical habitats through time, and a parallel monitoring of the biota synchronously in space and time (Belletti et al. 2017). The available hydromorphological survey data, however, may not fully cover all physical habitats relevant for the biota. The hydrological stations measuring flow dynamics may not be sufficiently close to the biological sampling stations, and hydrological modelling may be too uncertain to establish significant pressure-response relationships. The usual approach for analysing these relationships is 'space-for-time substitution', in which impacts at one site over time including succession mechanisms, or transient and legacy effects remain concealed (Wiegleb et al. 2016).

In the CIS workshop on river hydromorphological assessment and monitoring (Madrid, November 2017), it was concluded that in order to quantify the links between hydromorphology and biology, it is crucial that a sound monitoring is carried out in sub-reaches that are homogeneous in terms of hydromorphological conditions; existing water bodies may or may not be suitable for this so as to comprehend the typical assemblages of hydromorphological features for that river type. In such a reach the biological sampling should take place, together and in relation with all hydromorphological features in the sub-reach, in a real multi-habitat perspective. This will optimize the interpretation of the links between hydromorphology and biology.[10]

Related questions:

Q11. How have indicators of hydromorphological QE been matched with BQEs to validate sensitivity to hydromorphological pressures?

3.6. Multiple pressures

In multi-pressure contexts, pressure-response relationships tend to reflect the limiting factors rather than individual pressure effects. This is displayed by 'wedge-shaped' pressure-response plots where, for instance, the 95th percentile regression line would indicate the maximum pressure-levels that allow for a certain biological status. In turn, this means that clear-cut relationships with single pressures explaining a large proportion of the variability in biological status are not to be expected (similar situation for physico-chemical pressures in multi-pressure contexts). In terms of multiple pressures involving river channelization and nutrient enrichment, the EU MARS research project revealed small antagonistic effects on benthic invertebrates and fish, putatively caused by faster current velocity and better oxygen exchange related to it (unpublished).

4. Hydromorphological assessment in support of BQE methods to classify ecological status

This section addresses the use of hydromorphological assessment as a supportive QE in the overall classification of ecological status. In the CIS workshop on river hydromorphological assessment and monitoring (Madrid, November 2017), it was concluded that in some cases, and especially where existing biological methods are not responding to hydromorphological pressures, hydromorphological

[10] Ibid.

assessment can be used as proxy for ecological assessment.[11] Hydromorphological methods are generally capable of providing the most comprehensive assessment of hydromorphological pressures. BQE methods sensitive to hydromorphological pressures often address only selected aspects of hydromorphology (e.g. river channelization, longitudinal connectivity). Furthermore, most Member States hold hydromorphological assessment methods distinguishing between at least five status classes (see Annex). This raises the question of how Member States use the hydromorphological classification in support of the biological classification to determine ecological status (irrespective of whether the national BQE methods are sensitive or insensitive to hydromorphological pressures).

4.1. High status class

According to the WFD prescriptions the high hydromorphological status shall be defined per water body type for all indicative hydromorphological QEs (e.g. for rivers: morphological conditions, hydrological regime, river continuity). This high hydromorphological status is defined as that occurring at "totally or nearly totally to undisturbed conditions" (WFD Annex V), and consistently should be the high biological status (reference conditions, defined as the conditions associated with that type under undisturbed conditions showing no, or only very minor evidence of distortion).

Related question:

Q12. Member States have defined the high hydromorphological status in different ways (see Madrid report). How were the definitions of high hydromorphological and high biological status aligned?

4.2. Other status classes

Related question:

Q13. How is the hydromorphological classification used in support of the BQE assessment to classify the ecological status below the high status class?

5. Questions for discussion

The following list is a summary of all questions outlined in the previous sections:

Q1. What are the main challenges in developing biological assessment methods sensitive to hydromorphology?

Q2. Which BQEs are used to assess the effects of hydromorphological pressures, which indicative parameters and bioassessment metrics/features of the biological community are most relevant?

Q3. How was the sensitivity of your BQE method(s) to hydromorphological pressures validated?

Q4. Has your BQE method sensitive to hydromorphology been intercalibrated successfully?

Q5. Is a pressure-specific BQE method for hydromorphology in place in your country? Which specific types of hydromorphological pressures are covered?

Q6. Do you use the same typology for biological and hydromorphological assessment in your country?

Q7. Do the biological reference conditions in your country sufficiently consider the biological variability at high status due to different hymo-types within a particular WFD water body type?

Q8. Have biological monitoring sites been selected in consideration of hydromorphological conditions/processes within WFD water body types?

Q9. Which hydromorphological quality elements (morphology, hydrology, continuity) relate to your national BQE methods?

[11] Ibid.

Q10. Are your BQE methods/metrics related to different hydromorphological pressures (e.g. flow reduction, channelization, hydropeaking)?

Q11. How have indicators of hydromorphological QE been matched with BQEs to validate sensitivity to hydromorphological pressures?

Q12. Member States have defined the high hydromorphological status in different ways (see Madrid report). How were the definitions of high hydromorphological and high biological status aligned?

Q13. How is the hydromorphological classification used in support of the BQE assessment to classify the ecological status below the high status class?

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2015 CIS Workshop conclusions on Hydromorphology and WFD classification.

Annex: Use of hydromorphological assessment methods for status classification in European countries

Country	Number of classes in Hymo classification method	Ecological status classification (for confirming high ecological status only/downgrade to GES)	Ecological Status classification (for classification in all ecological status classes)	Notes
Austria	5			It can be used directly for classification only if no biological assessment is available and in clear-cut situations and status is then classified to be of low confidence
Belgium Flanders	5			
Belgium Wallonia	5			
Switzerland	5			
Cyprus	?			Not used for ecological classification
Czech Republic	5			Not used for ecological classification
Germany	5/7			Three different methods; all
Denmark				Not used for ecological classification
Estonia	?			It can be used directly for fish biological assessment in case of significant barriers
Spain	3			
Finland	5			Used as a proxy for significant HyMo pressures; rarely used for ecological classification in classes lower than good
France	5			
Hungary	5			
Ireland	5			New method in development
Italy	5			Also used for identification of HMWB
Lithuania	3			Boundaries for moderate/poor and poor/bad status class are not determined
Luxembourg	5			
Latvia	2			
Netherlands	5			Not used for ecological classification
Norway				Norway has no hymo assessment measure but pressures analysis sensu WFD art. 5.

Country	Number of classes in Hymo classification method	Ecological status classification (for confirming high ecological status only/downgrade to GES)	Ecological Status classification (for classification in all ecological status classes)	Notes
Poland	5			
Portugal	5			
Romania	5			
Sweden	5			Legislation requires assessing hydromorphology in all status classes. A consistency and uncertainty analysis is required in all WB to check if hydromorphological and physico-chemical status is consistent with the ecological status set by BQE. If not consistent and hydromorphological assessment is assumed correct, the BQE can be ruled out. The BQE should then be assessed on expert judgement based on pressure-state knowledge.
Slovenia	5			Under development
Slovakia	5			
Turkey	5			
UK-England Wales	5			
UK-Northern Ireland	5			
UK-Scotland	5			Hydrological method supports only the high ecological status classification

Source: Kampa, E. & Bussettini, M., 2018. River Hydromorphological Assessment and Monitoring Methodologies. Final report - Part 1: Summary of European country questionnaires.
Note: Green colour indicates that at least one method was reported as relevant to this aspect in the submitted questionnaires.