# Consideration of hydromorphology and sediment in the implementation of the EU Water Framework and Floods Directives: a comparative analysis of selected EU Member States

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**Abstract**

The EU Water Framework and Floods Directives represent important legislative instruments introduced in the water policy during the last two decades. Despite their holistic and complementary approaches, which should yield many benefits, the lack of importance given to the consideration of hydromorphology and sediments is a weakness. This will hinder the achievement of the Directives' goals, since hydrology and geomorphology of rivers and the character and dynamics of sediments are essential components of the aquatic habitat and ecosystem health. The entrainment, transport and deposition of sediments determine the interrelationships between river channel geometry and flow regime, which affect flood risk. The paper reports on the findings of a survey undertaken in 2015 as part of the HYTECH project, which questioned 20 EU Water Authorities about the importance they attached to hydromorphological quality elements and sediment transport during the implementation cycles of both Directives.

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Water Framework Directive, Floods Directive, Flood defence/management, Fluvial, Policy, River Basin Management, Sediments, Water

## Introduction

In Europe, the quality of freshwater ecosystems is one of the most important concerns for the future, as recognised by the EU Directive 2000/60/EC, namely the Water Framework Directive, hereafter called WFD (EU 2000). The Directive represents a new integrated approach to water protection, improvement and sustainable use, co-ordinates the application of other water-related legislations (e.g., Urban Waste Water, Drinking Water, Seveso Directive, Habitats and Species Directive) and provides a coherent management framework with the aim to meet its goals in an integrated way (Clarke et al. 2003, Brils 2008, Nones 2015a, Nones 2016). Moreover, the WFD introduces the management of rivers at the catchment scale, defining River Basin Districts based on geographical and hydrological characteristics, instead of using administrative or political boundaries. For each district, a River Basin Management Plan is established and updated every six years with a period for stakeholder consultation and detailed programmes of measures have to be set up in accordance with it. Of the several WFD deadlines, the most important one is the achievement of at least good ecological and chemical status for surface waterbodies and good quantitative and chemical status for groundwaters by 2027. Groundwaters are now covered by the Groundwater Directive 2006/118/EC, which has been developed after the Article 17 of the Water Framework Directive.

Following Article 2 of the WFD, “good ecological status” only permits a slight reduction in water quality when compared to the unmodified natural conditions for that waterbody type, assumed as the reference condition. Deviations from reference conditions are assessed by means of biological, hydromorphological, and physico-chemical quality elements. But it is only in the designation of high status that rivers must achieve hydromorphological characteristics (channel patterns, width and depth variations, flow velocities, substrate conditions, structure and function of the riparian zones) (Table

1) which "correspond totally or nearly totally to undisturbed conditions" (WFD, Annex V), and interestingly there is no recall to sediment transport. Thus, following this Annex and as explained in the CIS Guidance n° 13 (CIS 2005), European Water Authorities categorize waterbodies as achieving good, moderate, poor or bad ecological status *only* on the basis of biological monitoring results, without taking into account hydromorphological and physico-chemical quality elements (Kallis & Butler 2001).

**Table 1**. Hydromorphological elements supporting the biological elements in rivers.

| | | |
|---|---|---|
| *hydrological regime* | | |
| quantity and dynamics of water flow | | connection to groundwater bodies |
| *river continuity* | | |
| *morphological conditions* | | |
| river depth and width variation | structure and substrate of the river bed | structure of the riparian zone |

Source: adapted from Annex V, EU 2000.

Similar considerations are stipulated for heavily modified and artificial waterbodies: hydromorphological elements are taken into account *only* for rivers classified with the maximum ecological potential. In short, the classification criteria proposed by the WFD excludes the hydromorphological elements from the evaluation of watercourses at all levels apart from the classification of high status (Nardini et al. 2008, Nones 2015a). This means that rivers in good or lower ecological status may suffer from alterations to their hydromorphology, which could lead to a deterioration of the physical habitat, but these rivers will officially maintain their status. By neglecting the consideration of hydromorphological quality elements and sediment transport from a river's classification, the WFD may give a misleading and optimistic assessment of ecological status

(Nardini et al. 2008). Indeed, this shortcoming could potentially lead to deterioration that goes undetected, undermining the overall innovative approach of the Directive.

Inadequate consideration of hydromorphology and sediment transport also has implications for the Directive 2007/60/EC on the Assessment and Management of Flood Risk, hereafter called Floods Directive (FD). In the last two decades, Europe has suffered many flooding events, which have caused over 1000 fatalities, displaced about a million people, and resulted in at least 52 billion Euros of economic losses (EEA 2011, Hedelin 2015, Nones & Pescaroli 2016). Despite numerous technical and economic efforts to protect properties against floods, it is not possible to fully eradicate flood risk from human activities and possible climate change impacts have the potential to exacerbate future flood risk. Thus, the approach in Europe has shifted from protection against floods and flood defence to management of flood risks and resilience building (Fleming 2001, Defra 2005, POSTNOTE 2014, National Flood Resilience Review 2016, SEPA 2015), with the increasing use and integration of non-structural mitigation measures (like washlands or floodplains for flood storage and flow attenuation) and the use of spatial planning instruments (PPS 2009, Mostert & Junier 2009, Klijn et al. 2008, Müller 2013, Nones 2015b) and flood proofing measures. The principal aims of the FD are the reduction and management of the risks that floods pose to human health, environment, cultural heritage and economic activities. Like the WFD, each EU Member State is required to implement the FD at a national level by means of national legislation following compulsory deadlines and transnational measures are required by the FD for larger rivers which flow through several countries (EU 2007, Nones 2015b).

Despite Article 6.5d of the FD suggests drawing upon additional information regarding the impact of sediments and debris floods in the preparation of the Flood Maps (EU, 2007), after the first cycle ended in 2015 several shortcomings and weaknesses were apparent. These included the inadequate consideration of hydromorphological alterations and impact of sediments on flood risk and the cascading effects of floods (Nones & Pescaroli 2016). It is now timely to consider these as a basis for improving the next Flood Risk Management Plans, which will be produced by 2021.These plans

should contain information on changes and additional measures adopted, assessment of the progress made towards the achievement of the FD goals, description and explanation of measures foreseen in the previous plans, planned but not yet carried out (EU 2007, Nones 2015b).There is an aspiration that the synergies between FD and WFD will strengthen over time as river restoration activities such as re-meandering and floodplain reconnection deliver ecological improvements and more sensitive flood risk management (Skinner &Bruce-Burgess 2005, Wharton & Gilvear 2007, England et al. 2008). But differences in implementation, for example in methodological approaches and consideration of hydromorphology, have arisen between and within countries (Wendler 2007, Müller 2013, Nones 2015b).

To gain insights into the WFD and FD implementation cycles across the EU a questionnaire survey was developed and undertaken as part of the EU-funded project HYTECH, and sent to 40 governmental Water Authorities across the 28 Member States during 2015, which comprised the Authorities that are charged with the implementation in the 28 Member States and 12 German Länder. Germany comprises sixteen federal states (Länder), which have their own state constitution and autonomy in relation to their internal organisation.

This paper presents the findings of the questionnaire, capturing the situation in many countries at an important stage in both the implementation cycles, namely the publication of the second River Basin Management Plan and the first Flood Risk Management Plan. The focus of the survey was to ascertain how hydromorphology and sediment transport have been considered in the WFD and FD implementation process, and to explore possible synergies between the two Directives as a basis for informing future improvements to the Directives.

## Data and Methods

The HYTECH questionnaire comprised two sections (Table 2). *Section A* required a simple yes/no answer with the possibility to add information or guidelines as support, while *Section B* explored how hydromorphology and sediments are considered in the Directives, with a strong focus on sediment

transport. In *Section B*, a five point scale, spanning from 1 (no importance) to 5 (maximum importance) was used to score the responses (Table 3). Additional opportunities were offered to Water Authorities to express an opinion about the consideration of sediment transport through an open comments section.

**Table 2.** Questions posed in the HYTECH survey.

| | |
|---|---|
| *Section A* | |
| A1 | Are sediment transport and hydromorphological alterations considered during the biological monitoring programme? |
| A2 | Have sediment transport and hydromorphological alterations had an impact on the results of the biological monitoring programme? |
| A3 | In your national legislation, are hydromorphological quality elements considered for the WFD classification of rivers status? |
| A4 | Do you think that additional measures are necessary to keep the present river hydromorphology in the future? |
| A5 | Are sediment erosion and/or deposition considered in the modelling of the water discharge-stage relationship? |
| A6 | Is information about the impacts of sediment erosion and/or deposition on infrastructures reported in the Flood Risk Maps? |
| *Section B* | |
| B1 | In your opinion, how is hydromorphology limiting the achievement of Good Ecological Status or Potential? |
| B2 | In your opinion, how important is it to consider sediment transport in the River Basin Management Plans? |

B3 In your opinion, how important is it to consider sediment transport in the Flood Risk Management Plans?

**Table 3**. Analysis at the Member State level: consideration of sediment transport and hydromorphological alterations during the WFD/FD implementation process. Y=yes, N=no, N/A=no answer. The scale spans from 1 (no importance/limitation) to 5 (maximum importance/limitation).

| | A1 | A2 | A3 | A4 | A5 | A6 | B1 | B2 | B3 |
|---|---|---|---|---|---|---|---|---|---|
| Cyprus | N/A | N/A | N | Y | N/A | N | 3 | 2 | 2 |
| England | N | Y | Y | Y | Y | Y | 5 | 5 | 5 |
| Estonia | Y | Y | Y | N | N | N | 4 | 3 | 3 |
| Finland | Y | Y | Y | Y | N | N | 3 | 2 | 2 |
| Hungary | Y | N/A | Y | Y | N | N | 3 | 5 | 4 |
| Ireland | Y | Y | Y | Y | N | N | 1 | 3 | N/A |
| Italy | Y | Y | Y | Y | N | N | 3 | 2 | 1 |
| Luxembourg | N | N | N | Y | N | N | 4 | N/A | 3 |
| Scotland | N | N | Y | N/A | N | N | 4 | 4 | 3 |
| Bayern | Y | Y | Y | Y | Y | N | 4 | 2 | 2 |
| Brandenburg | N | Y | Y | Y | N | N | 4 | 3 | N/A |
| Niedersachsen | Y | Y | Y | Y | N | N | 4 | 3 | 2 |
| Saarland | N/A | Y | Y | N/A | N | N | 3 | 3 | 2 |
| Sachsen | N | N/A | Y | N | Y | N | 5 | 3 | 5 |
| Schleswig-Holstein | Y | Y | Y | Y | N/A | N/A | 3 | N/A | N/A |

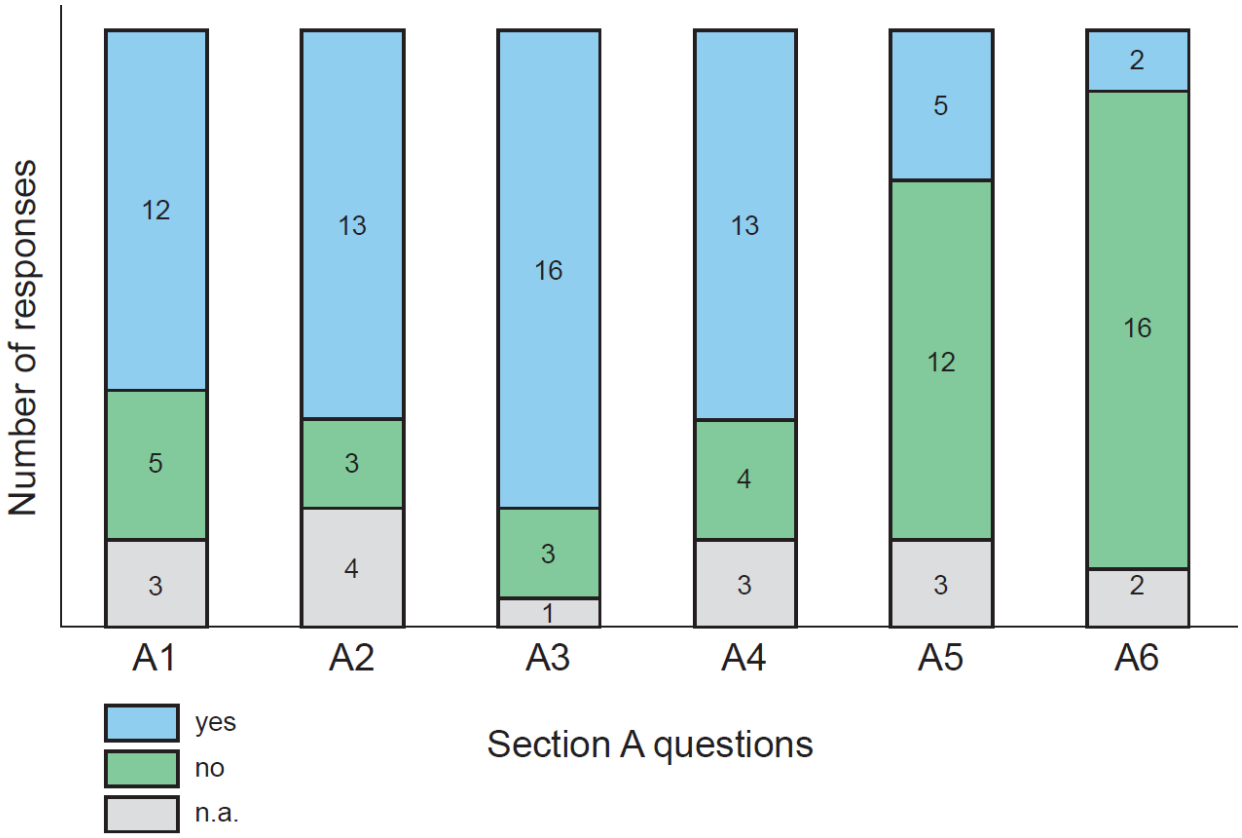
Note: Annex V of WFD (EU 2000) defines hydromorphological quality elements but does not consider sediment transport. Scale: 1=no importance/limitation; 2=low importance/limitation; 3=medium importance/limitation; 4=high importance/limitation; 5=maximum importance/limitation.

The questionnaire and an explanatory cover letter was sent to the contact person in the 40 identified Water and Environment Authorities. The respondents, which are reported in the supplementary material, were in comparable positions within each of the Authorities. By March 2016, 20 Authorities had sent back a completed questionnaire, and 15 gave permission for their responses to be published. The survey was time-limited, but these responses were considered as representative for the present situation in Europe with responses from Member States across a wide geographical area with differing river types and flood characteristics. A follow-up phase is planned, and future answers will be analysed to provide a more complete perspective. The first section of the Results presents the outcomes of the 20 Authorities (12 Member States and 8 German Länder) in an aggregated way, while the data reported in the second section refer to the countries and Länder that gave permission for the publication of data; namely Cyprus, England, Estonia, Finland, Hungary, Ireland, Italy, Luxembourg, Scotland and Germany (Länder of Bayern, Brandenburg, Niedersachsen, Saarland, Sachsen and Schleswig-Holstein).

## Results

*Analysis at the European level*

Comparison of the questionnaire outcomes for questions A1 to A4 with those for A5 and A6 shows how sediment transport and hydromorphological alterations are considered very important in the fulfilment of the WFD goals, but have a lower consideration in the Flood Risk Maps (Figure 1).




157

158 **Figure 1**. Consideration of sediment transport and hydromorphological alterations in WFD/FD
159 implementation: aggregated responses to Questions A1 to A6. Data were aggregated across 20 Water
160 Authorities (12 Member States and 8 German Länder). Questions are specified in full in Table 2.

161

162 Twelve Member States claim to monitor sediment transport, hydromorphological changes and biota
163 at the same time, to respect the legislative requirements and collect data necessary to evaluate the
164 impact of a changing morphology on the biological components. According to WFD requirements,
165 hydromorphological quality elements should be monitored during the WFD classification (A3), but
166 this monitoring does not need to take into account sediment transport. Despite this, sediment transport
167 is monitored in two German Länder, which consider its interaction with biota important for the
168 fulfilment of the WFD goals.

169 Regarding the FD, it is clear that sediments have a very low consideration: only five countries
170 consider erosion or deposition in the water stage-discharge relationship (A5), and account for
171 sediment transport in the production of Flood Risk Maps (A6). Among these Member States, only

three Authorities consider the feedback between sediment deposition/erosion and flood risk in the modelling of flooded areas.

The findings from Section B of the questionnaire are reported in Figure 2. Nineteen Authorities consider hydromorphology a limiting factor in the achievement of Good Ecological Status (B1). Half of the analysed countries recognize their importance, giving them a score of 4 (6) or 5 (4), while the other Member States assign them an average (6 with a score of 3) or lower (1 with a score of 1) significance. Comparison of the responses to questions B2 and B3 showed that a lower importance is given to sediment transport in the Flood Risk Management Plans compared to the River Basin Management Plans.

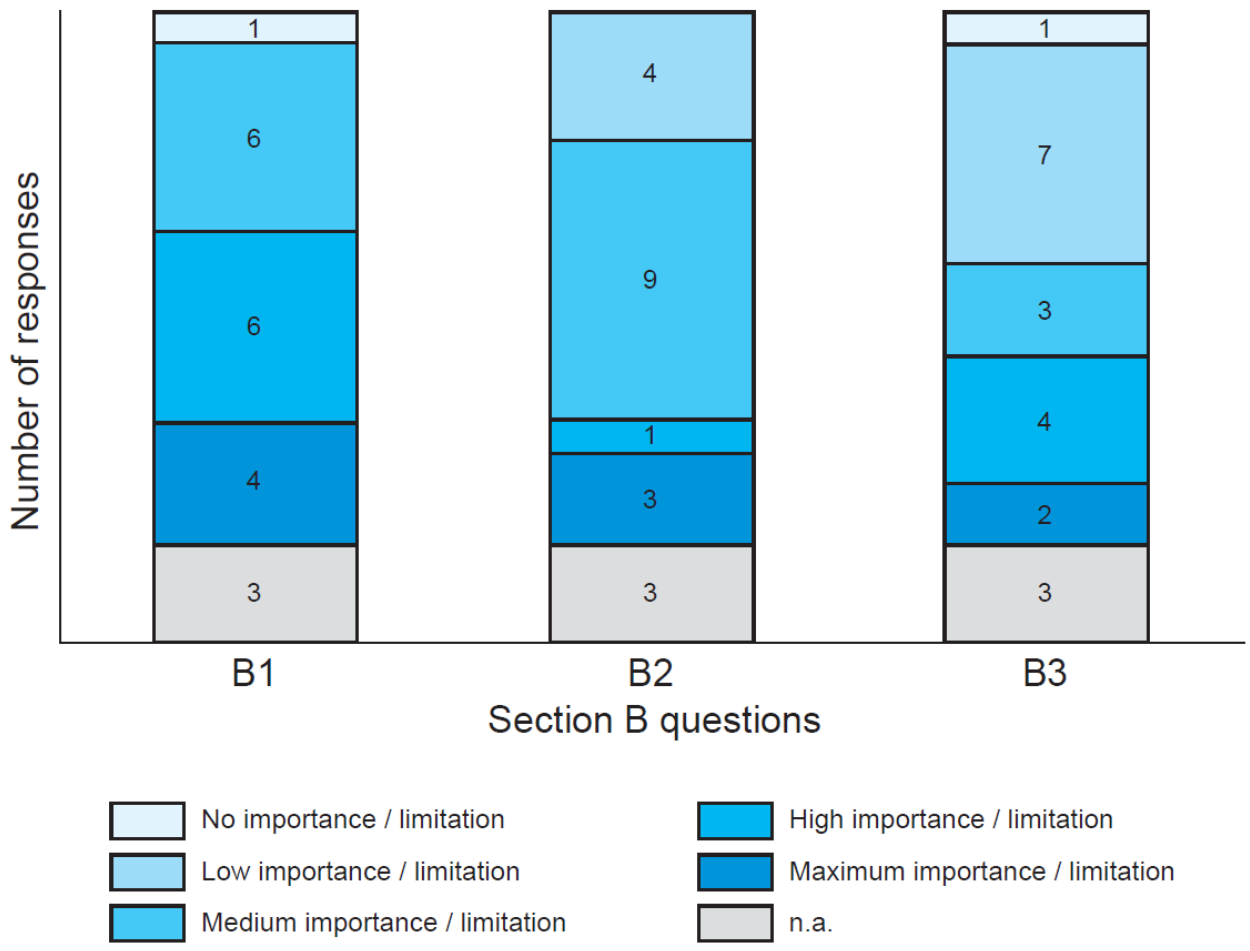



**Figure 2**. Responses to questions on how hydromorphology and sediment transport are considered

Analysis at the European level: limitation in the achievement of a good ecological status and

185 importance of sediment transport in River Basin and Flood Risk Management Plans. Data were
186 aggregated across 20 Water Authorities (12 Member States and 8 German Länder). Questions are
187 specified in Table 2.
188
189 *Analysis at Member State level*
190 Table 3 reports the importance given to sediment transport and hydromorphological alterations during
191 the WFD implementation process by the Water Authorities of each Member State (or Länder as in
192 the case of Germany). Some Authorities did not respond to all the questions, and, therefore, missing
193 answers are reported as N/A.
194 During the monitoring of biota for WFD implementation (question A1), sediment transport and
195 hydromorphological alterations are considered by Estonia, Finland, Hungary, Italy and three German
196 Länder (Bayern, Niedersachsen and Schleswig-Holstein), but they are not taken into account in the
197 monitoring programmes of England, Luxembourg, Scotland, Brandenburg and Sachsen. Cyprus and
198 Saarland did not provide information. However, sediment transport and hydromorphological
199 alterations (A2) are thought to have had an impact on the biological monitoring results in all the
200 responding Member States and German Länder apart from Luxembourg and Scotland (noting that no
201 information was returned for Cyprus, Hungary and Sachsen in Germany). Apart from Cyprus and
202 Luxembourg, hydromorphological quality elements are considered for the WFD classification in all
203 national laws (A3).
204 For the Water Authorities from Cyprus, England, Finland, Hungary, Ireland, Italy, Luxembourg,
205 Bayern, Brandenburg, Niedersachsen and Schleswig-Holstein, additional measures are considered
206 necessary to prevent future hydromorphological alterations of rivers, safeguarding present hydro-
207 morphodynamics, and allowing conditions to be accounted for in the future management plans (A4).
208 In contrast, Estonia and Sachsen consider the present measures as sufficient, while Scotland and
209 Saarland did not answer this question.

The Authorities of England, Bayern and Sachsen consider sediments in the modelling of the stage-discharge relationship (A5), while the other countries do not consider it or did not answer to the question (Cyprus and Schleswig-Holstein). Moreover, Bayern considers sediments in the modelling of the stage-discharge relationship (A5), but does not explicitly take them into account in the Flood Risk Maps (A6) and did not give additional information regarding this aspect. Finally, only England added information regarding the impact of sediments on infrastructures (A6), following Article 6 of the FD.

Hydromorphology is generally considered to be limiting to some extent in the fulfilment of the WFD goals, as evident from the scores reported for question B1. Only Ireland gave a score of 1, indicating no limitation related to hydromorphology. As previously observed, the WFD does not consider sediment transport as part of hydromorphological quality elements (Table 1). Apart from Luxembourg and Schleswig-Holstein, all the EU Member States responding to this survey place some importance on the consideration of sediment transport in the River Basin Management Plans (B2). However, the level of importance attached to sediment transport varies between Member States with scores ranging between 2 (Cyprus, Finland, Italy and Bayern) and 5 (England and Hungary). There is also a variable response in relation to the consideration of sediment transport in the Flood Risk Management Plans (B3) and overall a lower importance is assigned, as well as a higher percentage of missing responses.

## Discussion

EU Member States are required to schedule monitoring programmes for surface and groundwater bodies to establish a comprehensive overview of water status within each River Basin District (Article 8 WFD). For surface waters, these programmes cover the ecological status, without any compulsory consideration of the hydromorphological quality elements, which are a matter of the Annex V. Despite the specification of hydromorphological components within the WFD, hydromorphology is considered only as a supporting element for the assessment of the ecological status of many European

watercourses up to good status, and it is only in the classification of high status that hydromorphological characteristics are specified and must reach or approach undisturbed conditions. Moreover, there are no specific requirements to consider sediment transport in the WFD Directive and monitoring programmes.

Regardless the acknowledged interrelationships between hydromorphological alterations, sediment transport and biota, and the fundamental importance of hydromorphological diversity for ecological diversity and status, only 12 out of the 20 analysed countries monitor these parameters at the same time. Furthermore, the responses to the questionnaire highlight that several Authorities give a very low consideration to sediments in the River Basin and Flood Risk Management Plans. The quantity, quality and dynamics of sediments in rivers has the potential to influence the ecological (WFD) status of rivers and through hydromorphological changes stage-discharge relationships and flood risk will also be affected (Slater et al., 2015). But of the Member States and German Länder that responded to the questionnaire, only England, Bayern and Sachsen consider sediment transport. To address its lack of consideration a rethink of national legislation is necessary, as well as an improvement of the available EU guidances, which should be more focused on the causal inter-relationships between hydromorphological alterations, sediment transport, and the biological (ecological) status of freshwater ecosystems.

From a technical point of view, monitoring programmes need to be adjusted to accommodate the consideration of hydromorphology and sediments in future River Basin and Flood Risk Management Plans, at the same level as biological and physico-chemical ones. But such programmes will need to also consider the delayed effect that sediment transport has on the riverine biology and, therefore, monitoring timescales will require careful thought.

## Conclusions

This paper has reported on the findings of a questionnaire which aimed to ascertain the level of consideration given to hydromorphological alterations and sediment transport by Water Authorities

of EU Member States during the WFD/FD implementation cycles. The survey of 20 respondents showed large variations between the different countries in the level of consideration given and the importance attached to hydromorphology and sediment transport in the implementation of the WFD and FD. Sediment transport is given a higher consideration in River Basin Management Plans (WFD) compared to Flood Risk Management Plans (FD). The survey outcomes can be used as basis to inform dialogue and consultation of how sediments and hydromorphology might be included in the future WFD/FD implementation cycles. But it would be beneficial to seek responses from further Member States and explore in greater detail how sediment and hydromorphology are considered in those countries. Accompanying research is also needed on the interrelationships between sediment transport, hydromorphology and biota and the time-scales required to monitor hydromorphological change in the context of WFD and FD implementation and assessments.

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