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A FRAMEWORK TO DERIVE MOST EFFICIENT RESTORATION MEASURES FOR HUMAN MODIFIED LARGE RIVERS

CHRISTIAN WOLTER, UTE MISCHKE
Depts Biology and Ecology of Fishes and Limnology of Shallow Lakes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, Berlin, 12587, Germany

TANJA POTTGIESSER, JOCHEM KAIL, MARTIN HALLE
umweltbüro essen (ube), Bolle and Partner GbR, Rellinghauser Str. 334f, Essen, 45136, Germany

KLAUS VAN DE WEYER
lanaplan GbR, Lobbericher Str. 5, Nettetal, 41334, Germany

MATTHIAS REHFELD-KLEIN
Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz, Brückenstr. 6, Berlin, 10179, Germany

With the implementation of the Water Framework Directive (WFD), the European Union aims to reach the good ecological status of all surface water bodies of their member states until 2015. Slightly lower ecological quality aims will be accepted for artificial and heavily modified water bodies: the good ecological potential (GEP). However, until now only a common agreement exists about a restoration measures driven approach to derive the GEP, without proper evaluation of the measures itself. A comprehensive catalogue of 42 restoration measures has been compiled from various sources. By comparably evaluating their effectiveness for all four biological quality components macrophytes, phytoplankton, macroinvertebrates and fish independently, for the first time a most consensus group of 26 mitigation measures has been derived with more than average ecological effectiveness for more than one indicator taxon. In particular channel modifications in combination with reconnecting backwaters or the creation of shallow littorals have been identified as most promising to reach the GEP in artificial and heavily modified water bodies. However, the mitigation measures suggested might also become part of river basin management plans were the good ecological status is the main objective. According to the pressures being addressed, this framework should allow identifying and selecting the most efficient methods to improve the ecological quality for all indicator groups within the narrow timeframe of the WFD.

INTRODUCTION

Rivers have been used as an economic resource for centuries and economic development has physically altered them for navigation, flood control, hydropower production and other purposes. With the implementation of the Water Framework Directive (WFD) a legal framework has been established to protect and restore waters throughout Europe aiming to reach the good ecological status of all surface water bodies until 2015. However, in the European Union an average of 40% of surface water bodies have been identified as being at risk of failing to achieve the environmental objectives by 2015 as reported in the first status assessments at the end of 2004 [11]. For example, in Germany 60% of all surface water bodies (62% of rivers) were considered "at risk" of failing the WFD objectives and further 26% "possibly at risk" [6].

Hydro-morphological alterations emerged as top pressure. Hydropower generation, navigation and flood protection are important and widespread water uses responsible for significant hydro-morphological changes to Europe's water bodies. Several of these structural and physical alterations like regulation, channelization and damming are so significant – but socio-economically important, and thus, irreversible – that the WFD provides a mechanism to reconcile economic activity with environmental goals by allowing member states to classify water bodies as artificial (AWB) or heavily modified (HMWB) [10, 21]. The Netherlands have provisionally identified 95% of their water bodies as heavily modified and artificial, Belgium, Slovak and Czech Republic more than 50% each, and all other member states on average around 16% [11]. In the German part of the River Elbe catchment (97,175 km²) 65.9% of rivers were considered at risk and further 24.8% at unclear of failing the environmental objectives of the WFD. More than 11,000 barriers and dams and 273 reservoirs have been recorded, and 25.5% and 19.6% of water bodies provisionally designated as artificial respectively heavily modified [12].

The environmental objective for AWB and HMWB is the good ecological potential, which has been pragmatically defined as the ecological conditions expected when all suitable mitigation measures are taken except those that would have significant adverse effects on use, users or the wider environment and those that even in combination would only deliver slight ecological improvements [30]. By definition, the environmental objectives assigned to AWB and HMWB take into account the physical modifications due to their designation, and thus, only measures that will not have a significant adverse effect on the water bodies' designated use can be considered to mitigate adverse ecological effects of the modification. The ecological conditions predicted to result from these mitigation measures are used to estimate the values of the biological quality elements at GEP. However, the definition of GEP is a major challenge, because in many cases current knowledge is insufficient to precisely assess or model impacts of hydro-morphological alterations on the biological quality elements as well as effectiveness of mitigation or restoration measures.

Although river restoration has already become a widely accepted and commonly applied issue in environmental conservation [7, 31, 35, 40], evaluations of restoration measures are rather limited and little information were gathered about restoration success respectively effects [22, 36]. Despite the tremendous amounts of money spent for river restoration – within the continental U.S. about 14-15 billion $ since 1990 [2], in Canada 1322-7010 C$ per km salmon stream [23], in Germany 100-750 € per meter river bank [19] – the achievements of the environmental objectives have rarely been evaluated. Only 10% of 37,099 projects listed in the U.S. National River Restoration Science Synthesis database indicated that any form of assessment or monitoring occurred, however, most of these about 3700 projects were neither designed to evaluate the consequences of restoration nor to disseminate monitoring results [2]. Of 17 habitat improvement case studies along the German rivers Elbe, Main, Mosel and Rhine summarized [1] only a single one has been monitored for success: the effect of levee set-back on floodplain forest persistence. However, eleven case studies were mentioned of high and the remaining six of average ecological efficiency, although no validation occurred respectively was not at all considered in 50% of the measures [1].

After more than a decade of exponentially increasing restoration effort, and in view of the status assessments of the European surface water bodies and further tremendous rehabilitation efforts required, it seems insufficient to further state doing something might be more important than exactly knowing why. In contrast, the most efficient mitigation and rehabilitation measures have to be identified, implemented and rigorously evaluated to derive key measures to improve the ecological quality of waters.

This study aimed to identify key mitigation measures for the ecological improvement of AWB and HMWB and for the definition of their GEP in respect to hydromorphological pressures. Two approaches have been used to derive the GEP: 1) for selected water bodies of the River Elbe basin, the GEP has been developed for all four indicator groups independently using a taxa-driven bottom up approach to identify key requirements and habitat bottlenecks, 2) in a measures-driven top down approach available mitigation and revitalization measures have been compiled and their ecological efficiency evaluated according to how the bottlenecks are addressed identified in step one.

In contrast to Interwies *et al.* [19], this study primarily focused on the selection of most ecologically effective combination of mitigation measures, while their practical realization might be achieved at widely varying costs and efforts. Furthermore, it has been agreed not to consider costs for the definition of GEP and to accept that measure combinations used to define GEP might not be selected to achieve GEP [10, 30]. Given that the measures suggested will not compromise existing uses, the evaluation of the most cost-efficient realization mode seems secondary after identifying the most ecologically effective measures and measure combinations. For example, interrupted connectivity may result in failing the good ecological status upstream, however, an unrestricted functioning fish migration facility can be realized using numerous construction types at widely varying costs, but if lacking connectivity is the only pressure, the cheapest solution might be sufficient.

TAXA-DRIVEN APPROACHES

Ways to develop the GEP have been independently assessed for the different indicator groups based on comparative studies, case studies, potential mitigation measures as well as on identified habitat bottlenecks, as indicated below. The study area was restricted to lowland waterways within the River Elbe basin, Germany.

Phytoplankton

Due to a lack of reference sites in large rivers, background loads of total phosphor in the reference state have been reconstructed and used to reconstruct biomass and taxonomic composition of phytoplankton by extrapolation from the best available sites [28, 29]. Environmental parameters influencing the phytoplankton community were mainly water depth, average width, riparian vegetation and inorganic turbidity, all influencing the availability of light for growth and biomass production as well as discharge, flow velocity and catchment area influencing the water retention time and thus, growth period [28, 29]. Accordingly, the phytoplankton community will be mainly influenced by eutrophication, river regulation or navigation-induced turbidity, and less effected by rehabilitation measures targeting river morphology or instream structures.

In the urban rivers of Berlin total phosphor concentrations <90 µg l^{-1} seemed achievable by improved waste water treatment and the reduction of nutrients from diffuse sources and rainwater overflow [33].

Macrophytes

All available data on macrophyte stands and distribution within the River Elbe catchment, Germany, have been analyzed and several river stretches identified covered by dense floating vegetation rich in growth forms. In addition, pretentious aquatic macrophytes and aquatic reeds were found corresponding to the reference conditions for these river types [24, 44].

However, in most lowland waterways the euphotic depth suitable for submerged macrophyte growth was restricted to the 1 m isobath due to turbidity and related light extinction [3]. Accordingly, the availability of shallow littoral areas protected from wave wash was the main habitat bottleneck for macrophytes in degraded waterways.

Parameters for ecological assessment using macrophytes were cover of aquatic macrophytes and reeds, the diversity of growth forms and the presence of pretentious macrophyte species (details in [32]). In particular the growth form patterns and the number of different growth forms observed also depend on flow diversity and depth variability [43-45], whilst the pretentiousness of aquatic macrophytes is mainly related to water quality and eutrophication [15, 37, 38, 41].

Macroinvertebrates

In Germany like elsewhere in Europe [27] macroinvertebrates have been already used for decades to assess biological water quality of rivers based on indicator organisms [13, 14, 34, 42]. Not surprisingly, a highly sophisticated assessment system for the ecological quality of surface waters according to the WFD was first available based on macroinvertebrates [4, 16-18, 26].

Sampling is based on a multi-habitat sampling strategy, with a sample being composed of 20 spatially stratified sampling units and taxa identified to the species level. Assessment follows a stressor-specific multimetric approach. Three main stressors are considered in individual modules: saprobic pollution, acidification, and general degradation. The module general degradation reflects the impact of various stressors like hydro-morphological degradation, changes in stream hydrology, and impacts of land use. However, hydro-morphological degradation is the most important stressor usually determining the result of this module (detailed information on the assessment scheme PERLODES at http://www.fliessgewaesserbewertung.de/en).

The good ecological potential of the invertebrate fauna was developed using a four step approach: First, a list of taxa potentially occurring in the rivers investigated was compiled from present and historical data and each taxa assigned to the typical habitat required (e.g. sand in low velocity zones). Second, the extent of the different habitats after implementation of the mitigation measures was assessed. Third, taxa abundance was calculated according to the available habitats after restoration and 50 random subsets of this taxa list were generated mimicking taxa numbers and number of individuals commonly observed in real samples (electronic sub-sampling according to [25]). Forth, the randomly generated taxa lists served as input to calculate scores, core metrics and related metrics using the PERLODES assessment method for natural rivers. These assessment results described the good ecological potential of the invertebrate fauna. Major deficits or bottlenecks have been identified by comparing the PERLODES assessment results of the good ecological potential with the present state: the lack of limnophilic taxa and species preferring phytal or organic substrates caused by the impact of wave wash, lacking shallow littoral areas, and the removal of wood.

Fish

Fish environmental interactions have been analyzed by comparing the fish assemblage structure of altogether 27 lowland waterways in northeastern Germany. More than 500 sites have been surveyed several times, about 2,100 samples collected and more than 330,000 fish caught belonging to 39 species since 1993 [9, 47, 49, 52, 53].

The waterways surveyed provided an environmental gradient from rural regulated (6), rural artificial (8), urban regulated (5) to urban artificial (8) waterways. Their morphology ranged between 2.8-486 km length, 17-250 m minimum width, 1.5- 4 m minimum depth at mean discharge, and mostly negligible low flow velocities. Between 8.6% and 100% of the total shore lines were embanked with riprap or pile walls and had steep slopes. Submerged macrophytes were mostly absent and the cover of emerged macrophytes along the banks ranged between 0% and 90%, mostly less than 20%. All waterways were polytrophic to hypertrophic.

The fish assemblage structures differed highly significant between rural and urban waterways. Both, number of species (mean ± standard error: 20.2 ± 1.8) and Shannon's species diversity H' (1.82 ± 0.08) in rural waterways increased significantly ($p<0.05$ respectively $p<0.01$, *t* statistics) that of the urban (14 ± 1.3 and 1.47 ± 0.09). In contrast, the fish community in the urban waterways was significantly stronger ($p<0.05$, *t* statistics) dominated by two species only (73.3 ± 0.03% compared to 62.5 ± 0.03%). Similar results have been obtained by comparing artificial with regulated waterways irrespective of the land use. They significantly ($p<0.01$, *t* statistics) differed in species number (14.2 ± 1.2 *vs* 21.7 ± 2), species diversity (1.49 ± 0.08 *vs* 1.90 ± 0.07), and assemblage dominance of two species (73.6 ± 0.03% *vs* 59.1 ± 0.03%). Species with a presence of >90-100% and >60-90% of all surveyed waterways were considered as reference and accompanying species, together forming the group of type-specific species of the lowland waterway fish community [49, 51].

The availability of shallow littoral habitats protected from higher flows and wave wash for spawning and juveniles' nurseries have been identified as major habitat bottleneck for fish in waterways [48, 50]. Further, a threshold value of about 80% artificial embankments was found to qualitatively maintain most of the species, while the gradual increase up to complete embankment significantly impact on fish assemblage [46, 47, 50]. Even the final 10% of the total bank line, if remaining naturally or become covered by artificial embankments were reflected in highly significant fish-faunistic differences [46]. In waterways with "only" 90% of the shore lines embanked, the observed fish species numbers, species diversity and proportions of rheophilic, limnophilic, as well as threatened fish were significantly higher compared to completely embanked waterways. The dominance of the most tolerant, eurytopic species significantly increased with shoreline degradation, especially the dominance of perch [46, 47, 50].

MEASURES-DRIVEN APPROACH

Restoration and mitigation measures addressing hydro-morphological degradations have been compiled from several sources [8, 19-21, 30]. They belong to the six main categories reestablishing environmental sound hydraulics, promoting natural morphodynamics, improving connectivity, improving habitat quality of bed and banks, improving habitat quality of riparian zone and floodplain, and promoting natural flood protection, with altogether 18 sub-categories of up to four specific measures (Table 1).

From the total catalogue of measures all those have been excluded, which were expected to significantly impede existing uses, like dam removal. The remaining 26 measures were evaluated according to the habitat bottlenecks addressed and their ecological effectiveness expected (Table 2). The resulting effect matrix was dummy-coded (-1-3) and clustered using the Ward algorithm and squared Euclidean distances to identify significant groups of measures (Fig. 1). This procedure yielded two main cluster, one with overall low ecological effect sum including both measures impacting on fish (-1), and a second one with higher effective measures.

Table 1. Catalogue of potential measures to ecologically improve rivers (modified from [32]).

Objectives	Measures
Realizing river-type specific discharge	- deliver ecologically relevant minimum flow - deliver channel forming discharge - modify hydro-peaking
Lowering hydraulic impacts	- mitigate current-raising inflows
Improving bank features	- remove revetments, admit morphological changes - modify revetments - allow natural erosion and sedimentation processes
Improving bed features	- remove, modify bed fixation
Realizing sediment transport	- ensure sediment transport at weirs
Removing dams, weirs	- remove weir, dam - remove barrages - open, modify culverts, siphons
Modifying dams, weirs	- open, modify culverts, siphons - replace weirs by rocky ramps or glides - modify openings - remove impoundments
Bypassing dams, weirs	- construct bypass - construct fish migration facility
Creating type-specific river planform	- construct new channel with stream type-specific channel planform - enhance channel planform - elongate river course
Improving flow diversity	- create flow deflectors
Improving river-type specific substrate quality and diversity	- leave, introduce large wood - bed load management, bed load supply - allow longitudinal bars of typical substrates - improve typical aquatic vegetation
Protecting banks	- construct, modify alternative groynes - construct, modify parallel off-bank revetments - preserve, develop flow protected shallow littoral
Improving depth variability	- allow pool formation, preserve pools
Reducing maintenance and pressures	- ecologically sound water maintenance - ecologically sound inland navigation
Reducing, disposing entrainments	- water-considerate agriculture, land use - dredge fine sediments, mud - establish riparian buffer zone
Improving riparian and floodplain vegetation	- preserve, develop floodplain forest
Improving, creating floodplain habitats	- preserve, develop oxbows, backwaters - reconnect backwaters, relict channels - construct parallel channels
Reconnecting floodplains	- reactivate primary floodplain - establish secondary floodplain - raise river bed, low submersible dams

Table 2. Expected ecological effects of selected restoration measures on the biological quality indicator groups according to the WFD (- negative, 0 neutral, + slightly positive, ++ average positive, +++ highly positive).

	Measure	Effects on			
		Phyto-plankton	Macro-phytes	Macro-invertebrates	Fish
1	Remove revetments and admit morphological changes	0	++	+++	+++
2	Modify revetments	0	+	++	+
3	Admit natural erosion and sedimentation processes	0	+	+	+
4	Construct bypass	0	0	++	+++
5	Construct fish migration facilities	0	0	+	+++
6	Modify channel profile nature-like	+	+++	+++	+++
7	Create flow deflectors	0	+	+	+
8	Leave, introduce large wood	0	+	++	+
9	Bed load management, bed load supply	0	0	0	-
10	Allow longitudinal bars of typical substrates	+	++	+++	++
11	Improve typical aquatic vegetation	+	+++	++	++
12	Construct, modify alternative groynes	0	++	++	++
13	Construct, modify parallel off-bank revetments	0	+++	+++	++
14	Preserve, develop flow protected shallow littoral	0	+++	+++	+++
15	Allow, preserve pools	0	0	+	++
16	Ecologically sound water maintenance	0	++	+++	+++
17	Ecologically sound inland navigation	0	+	++	+++
18	Water-considerate agriculture, land use	++	++	+++	+
19	Dredge fine sediments, mud	++	+	+	-
20	Establish riparian buffer zone	+	++	++	++
21	Preserve, develop floodplain forest	++	++	++	++
22	Preserve, develop oxbows, backwaters	0	+++	++	+++
23	Reconnect backwaters, relict channels	++	+++	++	++
24	Construct parallel channels	0	+++	++	+++
25	Reactivate primary floodplain	0	++	++	+++
26	Establish secondary floodplain	0	++	++	+++

The second cluster underlined also the already mentioned difference between indicator value of the phytoplankton determined mainly by eutrophication and nutrients and the other taxa more pronounced responding to structural pressures. Accordingly, mitigation measures of higher efficiency for phytoplankton formed a sub-cluster with other measures of lower efficiency for macroinvertebrates and fish (Fig. 1).

Based on the clustering results a set of most consensus measures has been derived each considered to substantially improving at least two taxa. This subset was further subdivided according to efforts and time frame for realization and ecological effects (Table 3). Codes of conduct or best practice seemed most easily to apply, because they don’t need construction works and just modify common modes of operation to improve ecological integrity without compromising use. Instream habitat mitigation will not require additional land reclamation and was therefore considered as much easier to realize.

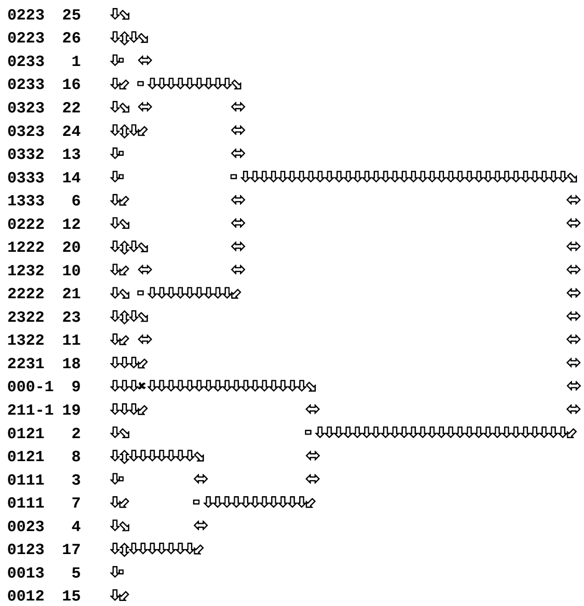

Figure 1. Ward-cluster (squared Euclidean distance) of preselected mitigation measures according to their ecological efficiency (effect matrix: from left phytoplankton, macrophytes, macroinvertebrates, fish; numbers refer to Table 2).

Table 3. Most consensus mitigation measures according to their expected ecological effects and time frame considerations (measure numbers refer to Table 2).

1. “Best practice” approaches – immediately realizable, significant effects until 2015

16	Ecologically sound water maintenance
17	Ecologically sound inland navigation
18	Water-considerate agriculture and land use

2. Restoration of instream habitat structures – short-term, significant effects until 2015

1	Removal of revetments and admitting morphological changes
6	Nature-like modification of channel profile
10	Allowing longitudinal bars of river typical substrates
11	Improving typical aquatic vegetation
13	Constructing and modifying parallel off-bank revetments
14	Preserving and developing flow protected shallow littoral areas
22	Preserving and developing connected oxbows, backwaters

3. Restoration of off-stream habitats – long-term ecological effects after 2015

20	Establishing riparian buffer zone
21	Preserving and developing floodplain forest
23	Reconnection of backwaters and relict channels
24	Construction of parallel channels
25	Reactivating primary floodplains
26	Establishing secondary floodplain

In addition, instream habitat improvements typically show immediate success, if essential habitat bottlenecks are addressed. Suitable habitats provided will be commonly utilized within one vegetation period and become more complex and diverse in the following years. In contrast, measures dedicated to riparian zones and floodplains improve the ecological integrity of floodplain river system in the long term. Aquatic communities more slowly react to stochastically available riparian or floodplain habitats, and those are more difficult to realize due to the additional requirement of available terrestrial areas.

In a final step, all core mitigation measures have been combined to analyze synergistic effects and to identify key measure combinations (Table 4). Phytoplankton was most improved by land use modifications to lower nutrient inputs in combination with floodplain vegetation development and backwater reconnections, while all other indicator taxa most benefited from channel modifications and the creation of shallow littorals. In total, a combination of main channel modifications with either backwater reconnection or shallow littoral areas performed best for predicted ecological improvements. The combination of channel modification and backwater reconnection might also serve the ecological improvement of phytoplankton (compare Table 2).

CONCLUSIONS AND RECOMMENDATIONS

In contrast to the definition of GEP, ecological conditions resulting from all efficient mitigation measures without adverse effects on uses, the final suggestion is a combination of two in maximum three mitigation measures. This corresponded very well with the major environmental bottlenecks determined for the taxa. Evidence is lacking in respect to hydro-morphological changes, that implementing additional mitigation to already successfully functioning measures or combinations will further significantly improve the ecological status, except a new important pressure would be addressed. There are nearly no restoration projects addressing more than one major pressure [36].

However, further research is needed in regard to 1) the cumulative as well as synergistic effects of mitigation measure combinations. For example, measures to improve the macrophyte-based ecological status might also improve the phytoplankton-based assessment. Macrophyte covers of 25% have been observed resulting in more than 50% reduction of phytoplankton biomass [39]. And 2) the spatial extension of mitigation measures. It is expected to become more important for mitigation success to cover a certain proportion of the water body instead of applying a certain number of measures.

It has been argued, that at places where biological condition are at its worst, rehabilitation efforts are unlikely to much improve biological condition [5]. However, especially the findings on fish assemblages in urban waters mentioned above [47] give opposite evidence. If at a very high level of artificial embankment a further reduction of the remaining 10% structured habitats causes a significant decline of fish, than also reversely, the rehabilitation of 10-20% of the bank line was expected to significantly improve fish abundance and diversity.

Table 4. Cumulative ecological effects from combination of rehabilitation measures for the single indicator taxa (above, from left phytoplankton, macrophytes, macroinvertebrates, fish) and in total (below). Measure numbers refer to Table 2.

		Remove revetments (1)	Modify channel (6)	Allow bars (10)	Improve vegetation (11)	Off-bank revetments (13)	Shallow littoral (14)	Water maintenance (16)	Inland navigation (17)	Land use (18)	Riparian buffer (20)	Floodplain forest (21)	Preserve backwaters (22)	Reconnect backwaters (23)	Parallel channels (24)	Primary floodplain (25)	Secondary floodplain (26)
1	Remove revetments		1,5,6,6	1,4,6,5	1,5,5,5	0,5,6,5	0,5,6,6	0,4,6,6	0,3,5,6	2,4,6,4	1,4,5,5	2,4,5,5	0,5,5,6	2,5,5,5	0,5,5,6	0,4,5,6	0,4,5,6
6	Modify channel	18		2,5,6,5	2,6,5,5	1,6,6,5	1,6,6,6	1,5,6,6	1,4,5,6	3,5,6,4	2,5,5,5	3,5,5,5	1,6,5,6	3,6,5,5	1,6,5,6	1,5,5,6	1,5,5,6
10	Allow bars	16	18		2,5,5,4	0,5,6,4	1,5,6,5	1,4,6,5	1,3,5,5	3,4,6,3	2,4,5,4	3,4,5,4	1,5,5,5	3,5,5,4	1,5,5,5	1,4,5,5	1,4,5,5
11	Improve vegetation	16	18	16		1,6,5,4	1,6,5,5	1,5,5,5	1,4,4,5	3,5,5,3	2,5,4,4	3,5,4,4	1,6,4,5	3,6,4,4	1,6,4,5	1,5,4,5	1,5,4,5
13	Off-bank revetments	16	18	15	16		0,6,6,5	0,5,6,5	0,4,5,5	2,5,6,3	1,5,5,4	2,5,5,4	0,6,5,5	2,6,5,4	0,6,5,5	0,5,5,5	0,5,5,5
14	Shallow littoral	15	19	17	17	17		0,5,6,6	0,4,5,6	2,5,6,4	1,5,5,5	2,5,5,5	0,6,5,6	2,6,5,5	0,6,5,6	0,5,5,6	0,5,5,6
16	Water maintenance	14	18	16	16	16	17		0,3,5,6	2,4,6,4	1,4,5,5	2,4,5,5	0,5,5,6	2,5,5,5	0,5,5,6	0,4,5,6	0,4,5,6
17	Inland navigation	14	16	14	14	14	15	14		2,3,5,4	1,3,4,5	2,3,4,5	0,4,4,6	2,4,4,5	0,4,4,6	0,3,4,6	0,3,4,6
18	Land use	16	18	16	16	16	17	16	14		3,4,5,3	4,4,5,3	2,5,5,4	4,5,5,3	2,5,5,4	2,4,5,4	2,4,5,4
20	Riparian buffer	15	17	15	15	15	16	15	13	15		3,4,4,4	1,5,4,5	3,5,4,4	1,5,4,5	1,4,4,5	1,4,4,5
21	Floodplain forest	16	18	16	16	16	17	16	14	16	15		2,5,4,5	4,5,4,4	2,5,4,5	2,4,4,5	2,4,4,5
22	Preserve backwaters	16	18	16	16	16	17	16	14	16	15	16		2,6,4,5	0,6,4,6	0,5,4,6	0,5,4,6
23	Reconnect backwaters	17	19	17	17	17	18	17	15	17	16	17	17		2,6,4,5	2,5,4,5	2,5,4,5
24	Parallel channels	16	18	16	16	16	17	16	14	16	15	16	16	17		0,5,4,6	0,5,4,6
25	Primary floodplain	15	17	15	15	15	16	15	13	15	14	15	15	16	15		0,4,4,6
26	Secondary floodplain	15	17	15	15	15	16	15	13	15	14	15	15	16	15	14	

At least modest improvements seem fully achievable. Improvements in heavily degraded areas can also reduce downstream effects and rehabilitate downstream reaches.

Finally it has to be mentioned that longitudinal connectivity is almost an important issue, even if it did not pop up here, because fish is the only suitable WFD indicator for connectivity and the only taxon significantly benefitting from migration facilities. However, migration barriers act very locally, but, if not properly mitigated, prevent the whole catchment upstream from reaching the good ecological status based on fish. This becomes particular important for barriers close to the mouth of larger catchments, for example the weir in the River Elbe at Geesthacht, Germany.

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