Hydromorphology of the Danube

Ulrich Schwarz

Abstract Hydromorphology describes the physical and hydrological characteristics of rivers and its habitats including the underlying processes from which they result. Hydromorphology is a supplementary but mandatory element of WFD ecological assessment, and hydromorphological alterations were recognized as one of the most important river management issues across Europe. Hydromorphological assessments try to integrate and provide information on how far the conditions derive from pristine conditions (so-called hydromorphological reference conditions). The ICPDR Joint Danube Survey (JDS) 2 in 2007 delivered results on hydromorphological alterations for the navigable Danube River (from Kelheim (rkm 2,416) to the Danube Delta) for the very first time. A five-class assessment similar – but not equal – to the WFD ecological status classes was implemented according to European standards and methodological approaches for large rivers using the three main categories (1. channel; 2.banks; 3. floodplains).

Keywords Banks, Channel, Danube, Floodplains, Hydromorphology, River morphology

Contents

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1 Introduction

Detailed and sectoral information on the geology, geomorphology, river cross sections and longitudinal profiles, sediments (e.g. grain size distribution and channel degradation), hydrology (discharge regime, amplitude and magnitude of floods) or floodplains and its vegetation are widely spread and analysed on catchment, river section and river reach scales, describing also the "river history" and the impacts of hydropower dams and river regulation for navigation and flood protection [1]. Therefore, hydromorphology considered as cross discipline of fluvial morphology/(river) hydrology, ecology and river engineering is one of the most challenging "river disciplines". It gained more awareness in the last decade of the twentieth century after solving the significant river pollution by sewage water in Western Europe from 1970 to 1990. From 1990 many EU countries developed hydromorphological methods and inventories.

The WFD adopted in 2000 includes hydromorphology as a supplementary but mandatory aspect of fulfilling the requirements for achieving the good ecological status in 2015. The results of the river basin analysis according to WFD Article 5, which was carried out in 2005, and of the river basin management plans published from 2009 strongly indicate the hydromorphological alterations across Europe (the European Environmental Agency [2] summarized that 50% of all European rivers are subject of considerable hydromorphological alterations). Solving this problem however requires a strong dialogue with other sectors such as hydropower development (Renewable Energy Directive), waterway transport (EU TEN Trans-European Transportation Networks), flood protection (EU Floods Directive) as well as the biodiversity and nature protection (Flora Fauna Habitat Directive).

To accommodate an increasing demand on harmonized methods, the CEN published in 2004 [3] and 2010 [4] important framework standards for hydromorphological assessments. In the case of the Danube and in large rivers in general, the applications are scarce and specific (e.g. [5]). The results of the hydromorphological assessments within the WFD should be used to supplement the ecological status assessment of water bodies and to indicate the "heavily modified water bodies". In currently strongly polluted water bodies not reaching the good ecological status, hydromorphological improvements can significantly improve the habitat conditions. Hydromorphologically intact river reaches can be seen as resilience hot spots (retreating area for many species) to be used in concepts aiming to reach the good status and to find best positions in the river continuum for restoration measures (so-called Strahlwirkungskonzept, [6] or [7]).

Hydromorphological alterations are recognized by ICPDR as one of the four basin-wide significant water management issues. The most significant alterations were categorized into longitudinal continuity interruptions (dams, weirs), lateral connectivity interruptions (loss of floodplains, bank reinforcements) and hydrological alterations (water abstraction (residual water) and hydropeaking).

The main impacts of hydromorphological alterations on the riverine habitats will cause the decline of species biodiversity, the decline of species abundance, altered population composition and hindrance of species migration and the corresponding decline of naturally reproducing fish populations (e.g. sturgeon).

2 Approach and Assessment

The lack of harmonized standard methods for the assessment of hydromorphological features on the Danube made it necessary to develop a methodology based on CEN ((EN146142004) for the assessment of hydromorphological features of rivers [3]) which could be applied for large rivers (compare [5, 8–10]). This method was used for the second Joint Danube Survey and consisted of a longitudinal overview survey evaluating the hydromorphological situation of the river and water bodies and of a detailed site survey which is needed for the interpretation of biological result at a particular sampling site.

The description and evaluation of hydromorphological characteristics for large rivers are strongly depending on various background data such as historical, topographical and navigation maps, satellite images, hydrologic and morphometric data as well as land use data (also for the determination of reference conditions) [10]. Hydromorphological assessment carried out during the second Joint Danube Survey was the first time that hydromorphological parameters were surveyed systematically by a uniform method for the entire navigable longitudinal Danube stretch over 2,415 rkm.

The hydromorphological parameters are supportive to biological quality elements for the assessment of the ecological status, primarily to the physical habitat description of fish, macrozoobenthos and macrophytes. Another issue for hydromorphology is to assess the capability of connected floodplains and natural channels to act as nutrient sinks, their resilience function after accidents with hazardous substances and their retention potential for flood protection.

The survey in general led to a better understanding of whether the river habitats are impacted by hydropower, navigation and flood protection. Based on the hydromorphological risk assessment, the “Programmes of Measures” as required by the WFD will be designed. To achieve the objectives of the WFD, it will also be necessary to set technical measures such as restoring continuity for migratory species or improving habitat conditions. Those stretches with still intact hydromorphological features threatened by navigation and hydropower projects should be protected or planning has to follow strict guidelines (compare [11]).

For the continuous longitudinal survey, a huge amount of already existing information and data were used to make a division of the Danube into homogenous about 50 km long stretches and to prepare the necessary data for the evaluation such as the general plan form and sinuosity, the main river engineering structures, longitudinal and lateral continuum interruptions as well as the floodplain with adjacent land use. The survey was used to update, approve and validate the preliminary results, especially those for the river banks. The five-class evaluation for channel, banks and floodplains was the base for the total evaluation using the mean values for the three categories [12].

3 Methods and Basic Variables

Preliminary subdivision to the river stretches was based on the river typology, water bodies, morphological characteristics and main hydrological alterations. The biological continuity interruptions were excluded from the assessment itself.

Channels were assessed using the following criteria: degree of morphological and flow condition alterations (based on hydrological alterations, navigation map, historical maps and plan form validated by field survey) and taking into account the type-specific reference conditions. Five classes were used for the assessment:

Class 1: Channel nearly natural
Class 2: Channel slightly modified
Class 3: Channel moderately modified
Class 4: Channel severely modified
Class 5: Channel totally modified

Banks (integration of left and right banks) were assessed by evaluating bank dynamics and modifications (based on navigation map, validated by field survey) taking into account the type-specific reference conditions. Five classes were used for the assessment:

Class 1: Banks nearly natural
Class 2: Bank reinforcements in small sections
Class 3: Bank reinforcements in large sections
Class 4: Continuous bank reinforcements
Class 5: Totally modified banks

[1] Not identical with WFD “ecological potential”.

Floodplains (integration of left and right floodplain) were assessed based on the ecological quality classes ("ecological potential"[1]) according to the DPRP Wetland study 1999 [13] considering the floodplain width (relation between active and morphological floodplain) and land use. Five classes were used for the assessment:

Class 1: Floodplain with very high ecological value
Class 2: Floodplain with high ecological value
Class 3: Floodplain with moderate ecological value
Class 4: Floodplain with low ecological value
Class 5: Floodplain totally modified

3.1 Overall Assessment

Five-class assessment (arithmetic mean) of channels, banks and floodplains with intervals of 1 for classes 2–4 and 0,5 for class 1 (reference conditions) and class 5.

3.2 Assessment Class Boundaries

1,0–1,4 = Class 1 reference conditions (blue)
1,5–2,4 = Class 2 (green)
2,5–3,4 = Class 3 (yellow)
3,5–4,4 = Class 4 (orange)
4,5–5,0 = Class 5 (red)

4 Results

During JDS2 66 homogenous stretches along the Danube River including the three delta branches (2,610 rkm) were delineated. The mean length of an evaluation stretch was some 40 km, (varying between 15–135 km). In general, the length of homogenous river segments increased from the upper to the Lower Danube.

4.1 Channel

Most of the hydropower plants in Germany and Austria fell into class 4 (severely modified). Totally modified, canalized and impounded Danube stretches can be found along the city stretches such as Vienna as well as in the Gabcikovo tailrace canal. Due to the compromise to assess longer river stretches, not all impoundments

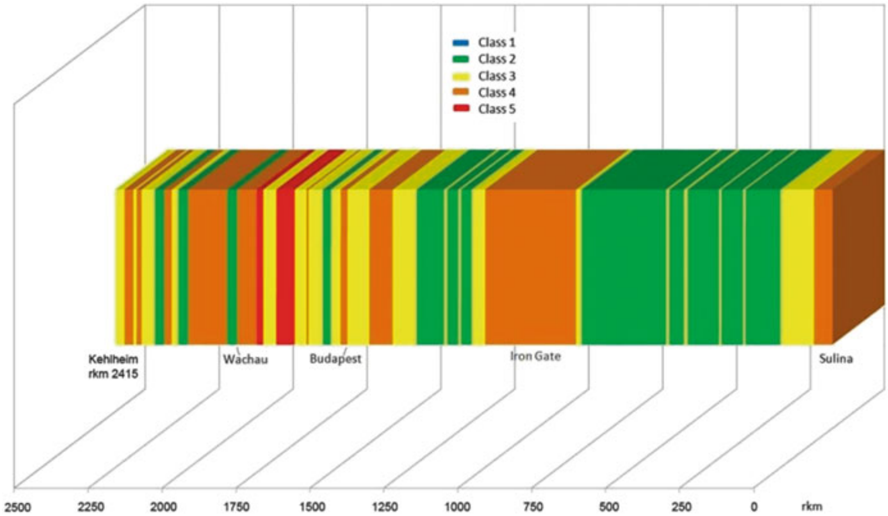

Fig. 1 Channel assessment as longitudinal colour-ribbon visualization

were reflected in detail so far. The total length of impoundments including backwater and transition sections would cover 1/3 of the river course. Barely moderate conditions can be found over the long free-flowing stretches in Hungary mostly due to the strongly reduced length of the river by meander cutoff since the eighteenth century, bed degradation (dredging) and navigation reasons (low-water regulation works). Still good conditions can be found in some breakthrough/gorges reaches such as Wachau (Austria) and Danube Bend (Hungary) and in the lowland stretches along the Croatian-Serbian border (without influence of the Iron Gate backwater). The largest stretches in good conditions were found along the Romanian-Bulgarian Danube. Still meandering reaches are very rare and most of the meanders were cut even within the last decades as such for the Sft. Gheorghe branch in the Danube Delta. None of the stretches can be assessed as class 1, due to river regulations for navigation and flood protection as well as due to the altered sediment balance (dams in the upper and middle course of the Danube and many tributaries) (Fig. 1).

4.2 Banks

The river banks are in particular enforced in Austria and Germany. Further downstream, the banks of the Danube are totally reinforced only in the area of towns. In the Hungarian reach, the banks are enforced in large sections (class 3). Along the entire Lower Danube, the bank reinforcement covers only few percent of the total river course, but local erosion protection activities increase currently the length of reinforced banks (Fig. 2).

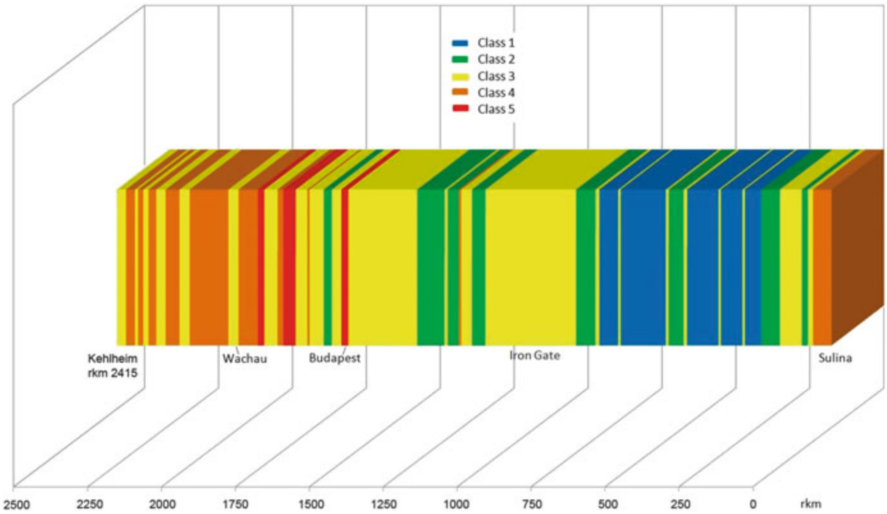

Fig. 2 Bank assessment

4.3 Floodplains

Most of the floodplains of the Danube (about 70% in total [14]) are disconnected by flood protection dikes, especially in areas where they spread over 10–20 km width along the Hungarian Danube south of Budapest and along the entire Romanian-Bulgarian stretch and towards the Danube Delta.

Only few reaches along the Danube have nearly intact or still remaining floodplains (21% in total according to Fig. 3). The largest existing continuous active floodplain areas along the Danube are as follows:

- Danube National Park (Austria): 10,000 ha
- Danube-Drava National Park (Hungary): 28,000 ha (Danube part only)
- Kopački Rit and Gornje Podunavlje Nature Parks (Croatia/Serbia): ~40,000 ha
- Floodplain forests of the Serbian Danube upstream of Tisza confluence: ~20,000 ha
- Small Braila Island protected area (Romania): ~20,000 ha
- Danube Delta (Romania, Ukraine): ~500,000 ha

In addition the remaining near-natural islands of the Lower Danube (Romania and Bulgaria) provide valuable and unique floodplain habitats as well.

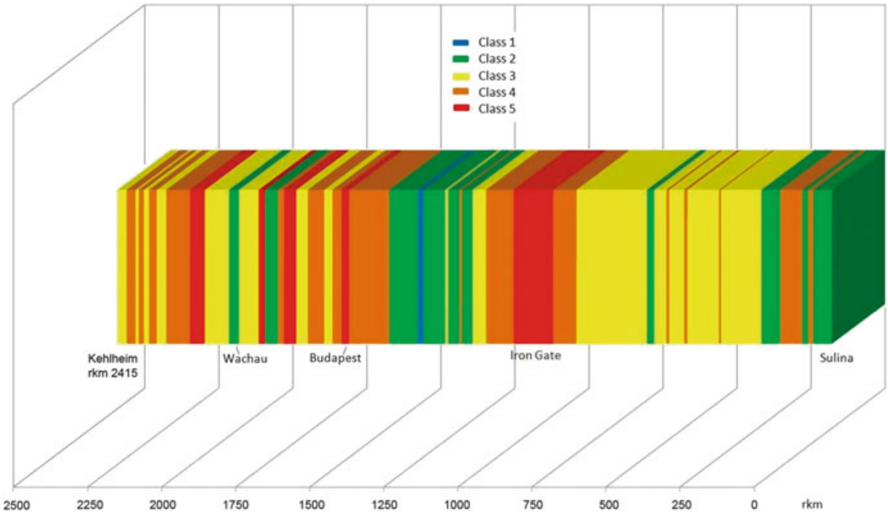

Fig. 3 Floodplain assessment

4.4 Overall Hydromorphological Assessment

One third of the Danube from Kelheim to the Black Sea can be characterized as strongly altered (classes 5 and 4) and another third as moderately altered (class 3). On the other hand, at least one third of the Danube belongs to the second, good hydromorphological class (see Fig. 4), which is a significant portion in comparison to other large rivers in central Europe. A more detailed analysis of the upper (Kelheim-Bratislava), middle (Bratislava-Iron Gate) and Lower Danube indicates that the upper reaches in Germany and Austria are those being most affected by significant hydromorphological changes. There are only small free-flowing stretches in that area such as Straubing-Vilshofen (Bavaria), Wachau Valley (see Fig. 4) or the Danube downstream of Vienna (Austria). On the other hand, the middle and lower courses of the Danube are interrupted and affected by the three large hydropower plants (the Gabcikovo Dam in Slovakia and the two Iron Gate Dams along the Serbian-Romanian border).

As for the "best available sites", only very short stretches (not visualized in this overall assessment) can be found within the highest class (class 1) for the assessment groups "banks" (along some steep banks of the Croatian-Serbian, Bulgarian and Romanian Danube) and "floodplains" (along the protected sites of Kopački Rit and the Gornje Podunavlje in Croatia/Serbia and on the right bank along the Small Braila Island in Romania). The channel itself is largely modified for navigation and only few kilometres remain along the island sections of the Romanian-Bulgarian Danube and in the major side channels along the less used delta branches where the highest class would be reached. The protection of those remaining "intact" stretches is essential. The necessary restoration activities along the Danube were already set,

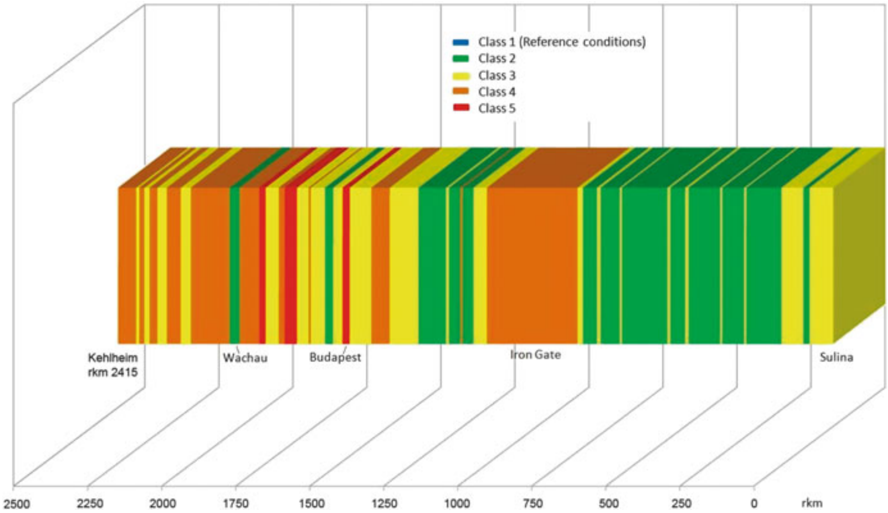

Fig. 4 Overall total hydromorphological assessment in five classes

e.g. at the Bavarian Danube (upstream Straubing) or the Austrian Danube (two fish passes in Melk and Vienna, restoration of the Danube National Park downstream of Vienna), to improve the ecological situation. Nevertheless these improvements cannot change significantly the overall situation along the Danube as they have importance mostly at the local and regional scale.

4.5 Results of the First Danube River Basin District Management Plan (DRBDMP) 2009

According to DRBDMP 2009 [15], 18 dams can be found on the entire navigable Danube reach from Kelheim to the Black Sea. Only at two dams fish migration facilities (bypasses at Melk and Wien-Freudenau) have been constructed and are in function. The backwater caused by the impoundments depends on the height of the dam and on the slope of the river course as well as on the discharge conditions (much longer backwaters during low-water conditions). The longest backwater (about 250 km) has the Iron Gate, while the shortest backwater reaches (about 5 km) can be found in Germany and Austria. In total DRBMP 2009 refers to 78 barriers including smaller weirs on the Upper Danube. The total official length of impoundments was estimated to be 1,111 rkm (including the non-navigable Upper Danube). Significant water abstraction along the navigable Danube can be found only at the Gabcikovo Dam. Hydropeaking was not defined for the Danube (not reaching the assessment mark of >1 m of daily water level oscillation); however, irregular water changes or slight daily peaking can be observed in the

Austrian Danube reach downstream of Enns confluence and downstream of the big dams (Gabcikovo and Iron Gate). Fifty-six percent of the entire Danube reach was designated as heavily modified water bodies.

5 Conclusions

The overall hydromorphological assessment indicates that the hydromorphological situation of the Danube varies from source to the delta. The hydromorphological conditions in the Lower Danube are much better than in the upper reach. In the DRBDMP 2009 [15], various measures were proposed improving the hydromorphological situation to reach the environmental goals for the period until 2015 and 2021, respectively (next full water management cycle). The first focus was set to the reduction of river continuity interruptions for migratory species. The construction of fish passes also for larger dams along the Upper Danube (in total five dams) is planned for 2015. A prioritization approach sensitive for migratory fish species and their habitats will support the further planning. Further activities are needed to improve the sediment transport through the chain of dams. As regards the lateral connectivity, few existing areas are planned to be reconnected until 2015 (in total about 45,000 ha [15] mostly within the active floodplain in protected areas such as national parks). For the Lower Danube, huge areas are under consideration to be reconnected by Romania. Finally the future infrastructure planning concerning the Danube should be based on the principles agreed in the "Joint Statement on the guiding principles for the development of inland navigation and environmental protection in the DRB" which defines environmental standards for inland waterway infrastructure projects [11].

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