Ecological benchmarking of the aquatic habitat changes in the Szigetköz floodplain of the Danube

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1 Introduction

The Szigetköz is one of Europe's last extensive inundated floodplains in the upper part (rkm 1850-1794) of the Hungarian-Slovak section of the Danube. Under the pristine conditions the course of the river changed within the floodplain on a broad scale forming a delta-like ana-branching channel pattern characterized by multiple channels, bars and unstable islands. The dynamic equilibrium of the natural system has undergone hydro-morphologic alterations due to river regulations since the end of the 19th century. The pre-regulation habitat composition has been considerably changed and habitat turnover became restricted, but the landscape still shows a mosaic of the old floodplain elements. The trends in the landscape change are ongoing, in the direction of a general loss of aquatic areas, especially with respect to dynamic rejuvenation zones. Terrestrialisation, the process of loss of aquatic areas by the accumulation of organic and inorganic sediments but also by a lowering of the groundwater table in the floodplain, is strongly accelerated.

Since the operation of the Gabčikovo hydropower dam in 1992 the environmental problems of the Szigetköz are increasingly recognised not only in the scientific community but also in society and governments, and interest has grown in restoring ecological functions of the river-floodplain system. Despite of some mitigation measures the degradation of the river ecosystem is obvious. The feasibility of rehabilitation scenarios of the Szigetköz section of the Danube was currently investigated in a Strategic Environmental Assessment, and within its frame a preliminary ecological benchmark system was developed for evaluation of habitat changes in the Szigetköz. The proposed ecological benchmarking involves the "functional unit" concept (Amoros et al. 1987, Potyó & Guti 2010) of large river ecology and includes quantitative and qualitative elements. The quantitative benchmarks concern the areal extent and proportion of aquatic habitats, with the reference of the historical habitat distribution. The qualitative benchmarks are based on the calculation of the Habitat-specific Fauna Index (HFI) and its relation to the bed shear stress distribution.

2 Elements of the quantitative benchmarking

The historical habitat analysis of the Szigetköz floodplain (Schwarz 2009) showed the reduction of total extent of the aquatic habitats, the decrease in the proportion of the eupotamon type arms and the alteration of aquatic habitat composition. According to these changes the quantitative benchmarking has three elements: 1) change of areal extent, 2) proportion of eupotamon, 3) habitat composition (Table 1). The 'integrated quantitative quality grade' is calculated from the total areal extent of the aquatic habitats (AE), the proportion of the eupotamon habitats (PEu) and the habitat composition (HC), following the 'one bad all bad' principle (see below).

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Table 1. *The five grade evaluation system of the integrated quantitative quality grade for the Szigetköz section of the Danube and its floodplain branch systems.*

Change of areal extent (AE)	Proportion of eupotamon (PEu)	Habitat composition (HC)	Integrated quantitative quality grade
< 20%	> 80%	all habitat types occur	*excellent*
< 40%	> 60%	one habitat type is missing	*good*
< 60%	> 40%	two habitat types are missing	*moderate*
< 80%	> 20%	three habitat types are missing	*poor*
> 80%	< 20%	more than three habitat types are missing	*bad*

3 Elements of the qualitative benchmarking

The key factors of the qualitative benchmarking are the discharge-controlled geomorphologic processes which create the characteristic patch dynamics and spatial distribution of flow velocity, shear stress and substrate grain size. These hydrological and geomorphologic variables provide the specific habitat conditions for characteristic fauna elements, which reflects the ecological quality of the aquatic habitats. The composition of the specific assemblages can be expressed by the Habitat-specific Fauna Index (HFI) used here for fish. It is based on summation of species habitat preference metrics as the habitat value and the indication weight. In order to describe the species' habitat preferences numerically, 10 valency points were distributed among six habitat types (Table 3). The valency point distribution is based on autecological knowledge, field observations as well as literature data. Species-specific habitat values (HV) are calculated according to the following equation (Chovanec & Waringer 2001, Waringer & Graf 2002, Chovanec et al. 2005):

$$HV = (1*H_1 + 2*H_2 + 3*H_3 + 4*H_4 + 5*H_5 + 6*H_6) / 10$$

The criterion for the differentiation of the habitat types was the lateral connectivity with the main channel: H_1 = Eupotamon A, H_2 = Eupotamon B, H_3 = Parapotamon A, H_4 = Parapotamon B, H_5 = Plesiopotamon, H_6 = Paleopotamon (Potyo & Guti 2010).

The indication weights (IW) ranging from 1 for eurytopic species to 6 for stenotopic species (Table 2) have been allocated to each species in order to identify the responsive (habitat indicator) species (indication weight ≥ 4). The indication weight is calculated from the valency point distribution.

Table 2. *Definition of the grades of the indication weight (IW) of the species*

IW	definition
6	Favoured habitat is scored 8-10 valency point
5	Favoured habitat is scored 6-7 valency point
4	Favoured habitat is scored 5 valency point
3	Favoured habitats are scored 3-4 valency point, sp. occurs at 4 habitat types
2	Favoured habitats are scored 3-4 valency point, sp. occurs at 5 habitat types
1	Favoured habitats are scored 1-2 valency point

The HFI is based on the summation of the habitat values and indication weights of all native species occurring at a given location. It is calculated using the following equation:

$$HFI = \Sigma\,(HV * IW) / \Sigma\, IW$$

where HV is the habitat value and IW is the species-specific indication weight. The HFI is calculated for locations and results in a number between 1 and 6, indicating habitat preference of the assemblage at the given location.

Table 3. *Habitat preference of the native fish species in the Szigetköz considered in the Habitat Specific Fauna Index (HFI). HV: species-specific habitat value, IW: indication weight. Rheophilic (HV < 2.5) spp. are indicated by light blue, and stagnophilic (HV > 4) spp. are indicated by apricot colour.*

fish taxa	eu A	eu B	Para A	Para B	Plesio	Paleo	HV	IW
Abramis ballerus	5	3	2				1.7	4
Abramis brama	2	2	3	2	1		2.8	2
Abramis sapa	5	3	2				1.7	4
Acipenser gueldenstaedtii	8	2					1.2	6
Acipenser nudiventris	7	2	1				1.4	5
Acipenser ruthenus	7	2	1				1.4	5
Acipenser stellatus	8	2					1.2	6
Alburnoides bipunctatus	10						1	6
Alburnus alburnus	1	2	3	2	2		3.2	2
Anguilla anguilla	2	2	3	2	1		2.8	2
Aspius aspius	3	3	2	1	1		2.4	2
Barbatula barbatula	8	2					1.2	6
Barbus barbus	6	3	1				1.5	5
Blicca bjoerkna	2	2	3	2	1		2.8	2
Carassius carassius					1	9	5.9	6
Carassius gibellio			2	3	3	2	4.5	2
Chondrostoma nasus	6	3	1				1.5	5
Cobitis elongatoides			2	3	4	1	4.4	3
Cottus gobio	10						1	5
Cyprinus carpio	1	2	3	2	2		3.2	2
Esox lucius		1	2	3	3	1	4.1	2
Eudontomyzon mariae		8	2				2.2	5
Gobio albipinnatus	5	3	2				1.7	4
Gobio gobio	3	4	2	1			2.1	3
Gobio kesslerii	6	3	1				1.5	5
Gymnocephalus baloni	5	3	2				1.7	4
Gymnocephalus cernuus		2	3	4	1		3.4	3
Gymnocephalus schraetser	7	3					1.3	5
Hucho hucho	9	1					1.1	6
Huso huso	7	3					1.3	5
Leucaspius delineatus				1	6	3	5.2	5
Leuciscus cephalus	3	3	2	1	1		2.4	2
Leuciscus idus	3	3	3	1			2.2	3
Leuciscus leuciscus	5	3	2				1.7	4
Lota lota	5	3	2				1.7	4
Misgurnus fossilis				1	3	6	5.5	5
Pelecus cultratus	6	3	1				1.5	5
Perca fluviatilis	1	1	2	3	2	1	3.7	1
Rhodeus amarus		1	1	3	4	1	4.3	2
Rutilus pigus	8	2					1.2	6
Rutilus rutilus	1	2	2	2	2	1	3.5	1
Sabanejewia balcanica	6	3	1				1.5	5
Salmo trutta fario	7	2	1				1.4	5
Sander lucioperca	1	3	3	2	1		2.9	2
Sander volgensis		2	4	3	1		3.3	3
Scardinius erythrophthalmus				1	5	4	5.3	4
Silurus glanis	1	3	3	2	1		2.9	2
Tinca tinca				1	3	6	5.5	5
Umbra krameri						10	6	6
Vimba vimba	5	3	2				1.7	4
Zingel streber	8	2					1.2	6
Zingel zingel	8	2					1.2	6
FI	1.61	1.8	2.18	3.85	4.29	5.23		

The assessment of the ecological quality (Tab.4) is based on a comparison between the pre-regulation river-type-specific reference assemblage and the recent assemblage. The pre-regulation reference fauna can be taken into account by study of historical literature and autecological knowledge. The ecological quality is classified by a five grade sorting scheme corresponding to the WFD evaluation system. A preliminary benchmarking of habitat alterations in the Szigetköz floodplain has been developed on fish data (Table 3) and it is focused on fauna changes in the eupotamon-A and -B type habitats:

1) Calculation of HFI by change of fish fauna in the eupotamon-A type habitat

- change of rheophilic sp. num. < -4 and
  change of stagnophilic sp. num. 0 **HFI < 1.70** fish biol. quality grade = *excellent*
- change of rheophilic sp. num. < -9 and
  change of stagnophilic sp. num. < +3 **HFI < 2.00** fish biol. quality grade = *good*
- change of rheophilic sp. num. < -15 and
  change of stagnophilic sp. num. < +6 **HFI < 2.45** fish biol. quality grade = *moderate*
- change of rheophilic sp. num. < -22 and
  change of stagnophilic sp. num. < +8 **HFI < 3.10** fish biol. quality grade = *poor*
- change of rheophilic sp. num. >-21 and
  change of stagnophilic sp. num. > +7 **HFI >= 3.10** fish biol. quality grade = *bad*

2) Calculation of HFI by change of fish fauna in the eupotamon-B type habitat

- change of rheophilic sp. num. < -4 and
  change of stagnophilic sp. num. 0 **HFI < 1.90** fish biol. quality grade = *excellent*
- change of rheophilic sp. num. < -9 and
  change of stagnophilic sp. num. < +3 **HFI < 2.30** fish biol. quality grade = *good*
- change of rheophilic sp. num. < -15 and
  change of stagnophilic sp. num. < +6 **HFI < 2.90** fish biol. quality grade = *moderate*
- change of rheophilic sp. num. < -22 and
  change of stagnophilic sp. num. < +7 **HFI < 3.50** fish biol. quality grade = *poor*
- change of rheophilic sp. num. >-21 and
  change of stagnophilic sp. num. > +6 **HFI >= 3.50** fish biol. quality grade = *bad*

Table 4. *The five grade evaluation system for the ecological quality of the eupotamon-A and eupotamon-B habitats based on Habitat-specific Fauna Index (HFI) calculated from fish data in the Szigetköz section of the Danube and its floodplain branch system*

Eupotamon-A	Eupotamon-B	Ecological (fish biological) quality grade
HFI < 1.70	HFI < 1.90	*excellent*
HFI < 2.00	HFI < 2.30	*good*
HFI < 2.45	HFI < 2.90	*moderate*
HFI < 3.10	HFI < 3.50	*poor*
HFI > = 3.10	HFI > = 3.50	*bad*

4 Evaluation of the habitat changes in the Szigetköz floodplain

The historical areal extent of the aquatic habitats was 4500 ha (Schwarz 2009) and the recent extent is 2360 ha (Potyó & Guti 2010). The shrinking was 48 %; therefore the *AE quality grade* of the Szigetköz floodplain is moderate. The proportion of the eupotamon habitat is recently 78 %, consequently the *PEu quality grade* is good. The recent composition of the aquatic habitats is similar to the historical composition, all main types of the aquatic habitats of the ana-branching sector exist, and the *HC quality grade* is excellent. The *integrated quantitative quality grade* of the floodplain is moderate by the 'one bad all bad' principle.

Habitat quality of the eupotamon type side arms was evaluated according to the long-term change of fish fauna. The fauna changes were determined by literature study and using database of direct ichthyologic monitoring (from the end of the 1980s). According to the expert judgement 39 fish species occurred in the eupotamon habitats of the ana-branching channel system in the pre-regulation situation and 77 % of the species was rheophilic. Their proportion decreased to 68 % and 51 % in the eupotamon-A and -B type habitats, respectively, until the beginning of the 1990s, and their ratio dropped to 61 % and 38 % recently. In the same time the number of the stagnophilic species increased and their proportion changed from 0% to 12% and 17% in the eupotamon-A and -B type habitats, respectively. The fauna changes can be indicated by the increasing trend of the HFI. The *quality grade of the HFI* was good in the eupotamon-A and moderate in the eupotamon-B type habitats before the operation of the Gabčikovo hydropower dam; however, it recently is moderate in the eupotamon-A and poor in the eupotamon-B type side arms (Figure 1).

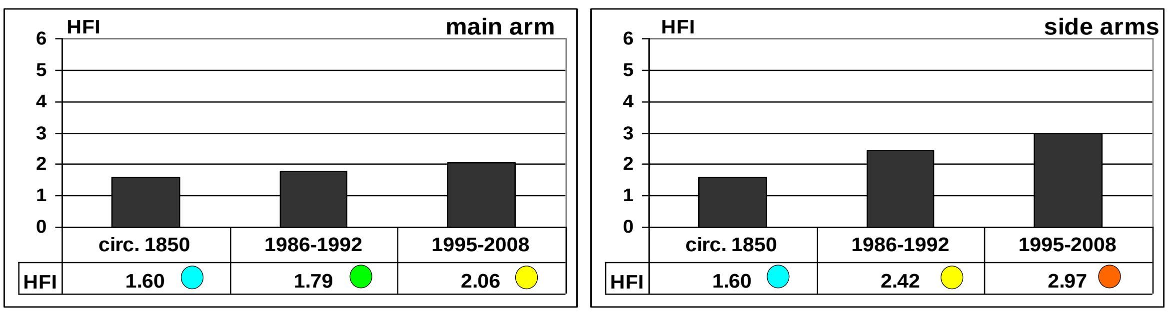

Figure 1. *Long-term change habitat quality is expressed by the Habitat-specific Fauna Index (HFI) for fish in the main arm (eupotamon-A) and in the side arms (eupotamon-B). Quality grade is indicated by colours: Blue = excellent, Green = good, Yellow = moderate, Orange = poor.*

The ecological status of the Szigetköz section of the Danube is good according to the biotic metrics of the official WFD assessment, and this grade seems overestimated if environmental deficiencies are taken into consideration. The evaluation of historical change and ecological quality of floodplain waters are neglected in the WFD assessment. On the contrary the proposed benchmark system takes the quantitative and qualitative attributes of the aquatic habitats into consideration; and it complements the recent assessment methods of the ecological status. Within the frame of its further development, application of the para-, plesio and paleopotamon habitats is reasonable, and the calculation of the HFI can be extended to other groups of aquatic organisms.

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