EVALUATION OF THE POSSIBILITIES FOR STREAM RESTORATION: PREASSESSMENT OF THE VÁLI-STREAM (HUNGARY)

ZSOMBOR BOROMISZA[1]* - ZSUZSANNA ILLYÉS[1] – ATTILA GERGELY[1] – SZILVIA MÉSZÁROS[1] – ZSÓFIA MONSPART-MOLNÁR[2]

1Szent István University, Department of Landscape Protection and Reclamation, 1118 Budapest, Villányi út 29-43., Hungary
2Herman Ottó Institute, 1223 Budapest, Park u. 2., Hungary
*Corresponding author: zsombor.boromisza@gmail.com

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Abstract
The purpose of this study is to evaluate the potential of restoration of a stream section. The starting point of the multiple-step assessment process was a historical analysis, which resulted in the definition of different sections within the study area, providing a base for the further restoration goals. The assessment of the current conditions was elaborated particularly to determine those factors, which could limit restoration. These assessments cover the land use pattern, furthermore the analysis of vegetation and habitat patches. As a result of the historical analysis, it has been found that the stream side habitat patches have decreased significantly despite the constant space available. This change was not caused by the increased area of the settlement, but rather by the higher dominancy of arable forms of land use. The greatest share of wet and mesic meadows and agricultural habitats in the study areas, covering 57.5% of the total area, indicates significant anthropogenic effects. Consequently it can be stated that the reference conditions are not the only determining factors of the restoration possibilities. Restoration style and intensity have been defined on basis of all assessed factors.

Keywords: stream restoration, ecological rehabilitation, landscape history, landscape planning, habitat mapping

1. Introduction

Streams in Central-Europe are affected by several environmental threats, their role – as a landscape pattern-determining feature – has decreased, their functions have changed (Báthoryné Nagy 2007; Mecser et al. 2009). In Hungary, according to the National River Basin Management Plan (KvVM 2009b), in lowland areas 95%, in upland areas 91% of the lower order streams are regulated. The improper management contributes to the adverse effects of stream regulation as well. Because of the estimated effects of climate change, a further decrease of stream discharges can be expected in the future. Among the environmental and ecological problems of lower order streams, many are related to the improper practice of urban water management, in numerous cases, streams are fed by polluted stormwaters and treated/untreated wastewaters. The most prevalent water quality issue concerning Hungarian surface waters is external organic matter and nutrient loading, beside lakes usually lower order streams are seriously affected, too (KvVM 2009a). Additionally, insufficient data can be regarded as a general problem, as far as quality assessment is concerned.

The channels of streams have been altered by water engineering interventions in the previous decades, instead of the natural course characters, straightened channels and trapezoidal cross sections were constructed (Szilágyi 2007). As a result, the velocity of the transported water increased, therefore the water regime became more extreme. The floodplain was reduced significantly by the construction of leeves. Thus, the main goal of stream restoration is to mitigate and manage the adverse affects of the engineered stream channels.

As landscape or settlement features, in many cases the lower orders streams no longer play an important part. Altered streams cannot be regarded as attractions, losing their landscape-forming potential in the development of open space systems (Illyés 2009), or in touristical issues. Besides, the requirements of the European Water Framework Directive, the development of potential recreational uses, leisure programs can contribute to the reconsideration of the role of lower order streams (Halasi-Kovács – Tótmérész 2007; Pomogyi et al. 2007).

Cost-effective, landscape-scaled rapid assessment tools can be used to prioritize restoration actions (Boromisza et. al 2014; Meixler – Bain 2010). The purpose of this study is to evaluate the potential for restoring a stream section, combining a historical analysis, and the assessment of the current ecological state and landscape pattern, through a case study (Váli-stream, Hungray). The main question is, having in mind the current landuse characteristics, to what extent the original character of the stream can be restored, and additionally, what is the realistic restoration goal of the different sections within the study area.

Over the last 30 years, river and stream restorations have become a widely applied approach to restore freshwater ecosystems (Bernhart 2007; Pander 2012). The assessment of channel morphology (Báthoryné Nagy – Novák 2005; Teufl et al. 2013), in riparian habitats (Kovács et al. 2011; Smiley – Dipple 2005), and the structural and functional connectivity between the stream and the surrounding landscape have become a subject of investigations (Báthoryné Nagy 2007; 2009). Stream restoration and the related actions are discussed both in theoretical reviews (Báthoryné Nagy – Novák 2007), and in several case studies, covering Germany (Pander 2012), the Netherlands (Verdonschot – Nijboer 2002), the United States (Alexander – Allan 2002; Bernhart 2007) as well.

Regarding measures of interventions, stream restoration – in many cases – is carried out by estabilishing wood in the stream channel, by the construction of vegetated buffers (Fischer – Fischenich 2000, Helfield – Diamond 1997; Mayer et al. 2006), by emergency chemical treatments (Kovács et al. 2012), or by channel adjustment (Miller – Kochel 2010). Beside the ecological advantages of stream restoration measures, renewed streamside landscapes could have an important role from the social aspect, thus, the public perceptions also have to be considered (Chin et al. 2008). Restoration of ecosystem functions in urban environments is especially challenging (Herringshaw et al. 2010). Accordingly, the fundamental touristic (Bendi et al. 2013; Nagy 2013) and spatial planning strategies (VÁTI 2009, 2014) of the study area were reviewed, too.

Evaluation of the most frequent riparian vegetation types of Váli-stream between Alcsútdoboz and Baracska was carried out on the basis of the most important ecological indicator values and coenological surveys (Mjazovszky – Tamás 2002; Mjazovszky et al. 2003).

2. Materials and methods

Study area

The catchment area (657 km^2) of the Váli-stream is situated in the foreground of the

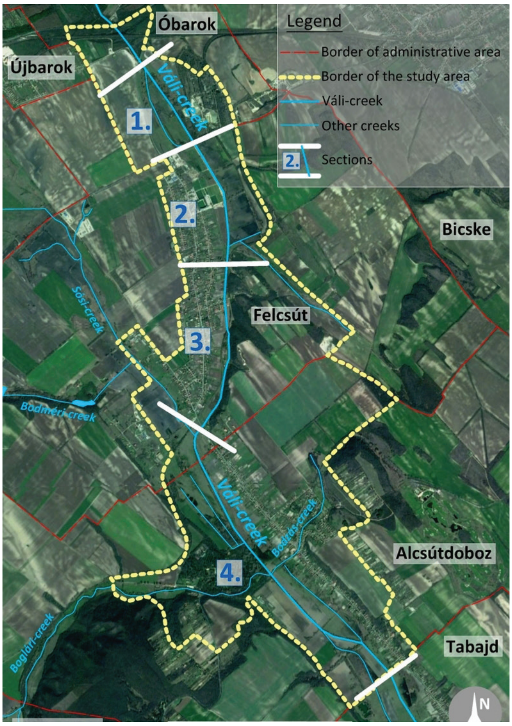

Fig.1. The location of the study area

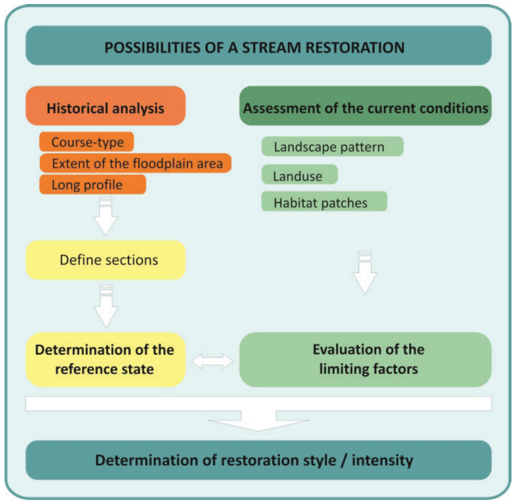

Fig. 2. Scheme of multi-step evaluation method

Trans-Danubian-mountains, between the valleys of the river Danube and Sió-channel. The stream valley is surrounded by 700-900 metres wide alluvial plain from both sides, dominantly sedimented by riverine sand, deposited during the Pleistocene (Dövényi 2010). The Váli-stream originated from several spring-heads at the toes of the Vértes and Gerecse mountains, flowing into the river Danube at Adony. The length of the Váli-stream is 56 km (Boda 2002). The water level of the stream is considerably fluctuating (KöDVGT 2010), seriously affected by seasonality of the karstic water level and mining activity. The study area is a 10 km long section of the floodplain along Váli-stream (see Figure 1.).

The lowering of the average water level of the stream is of high importance from the ecological point of view, as a result of the previous engineering actions, creating critical conditions especially on the upper sections of the study area in arid periods. The artificially straightened channel of the Váli-stream can be regarded as typical for the whole study area. The cross section of the stream was fitted to the simplified channel form, showing an absolutely geometric shape and regular slopes, in longer sections. The elevation between the stream channel and the surrounding terrain can be considerable, 2-3 metres differences can be found as well, spanned by vertical, artificial shorewalls (in section 3.). The management of the stream bed and and riparian zone is often means the complete cutting down of the vegetation of these habitats, in a few meters wide strip from the shoreline.

It is clear, that the non-point sources of pollutions originating from the intensive landuse connected directly to the stream (especially in Section 2. and 4.) resulted in a high level organic matter and nutrient loading to the water (fertilizers and chemicals used on arable lands). The effect of the sewage works in Újbarok (in Section 1.) can be regarded as one of the most significant sources of pollution. This is justified by water quality samples: the nutrient levels of the water (orthophosphate, nitrite) are considerably high in lower stream sections of the inlet point, remaining at a high level even in the southern sections of the study area, and can be characterised by eutrophic, tending to cause algal blooms (Pagony Táj- és Kertépítész Iroda 2013).

Assessment and evaluation methods

The potential of stream restoration was analysed in multiple steps (see Figure 2.). The starting point was a historical analysis, which resulted in the definition of different sections within the study area, providing a base for the further restoration goals. The assessment of the current conditions elaborated particularly to determine the factors which could limit restoration. These assessments cover the land use pattern, furthermore the analysis of vegetation and habitat patches. In the view of the historical reference state of the stream and the current limiting factors, restoration goals were determined for every section. The methodological details of the subtopics are described in the following.

Historical analysis

According to the recommendations of the river basin management plan (KöDVGT 2010) channel adjustment, modification of the long and vertical profile of the stream, renaturalization of the streambed are among the major tools of restoration. It means that knowledge is strongly needed on the natural / original characteristics of the target stream.

In Hungary, small (lower order streams) and medium sized lowland and hillside streams were regulated in the 19^{th} century, thus the description of the original channel – as a reference state – without historical documents is generally quite challenging. The design style of the historical military mappings could be regarded as a potential way of analysing the original conditions, covering several characteristics (Sallay et al. 2012): the original course-type, the spatial extent of the original floodplain – as a historical ecological corridor, the long profile.

The assessment of the original course-type: The representation of different types of wetlands is already fixed by the first historical military mappings, long before the theories on course-types and their characteristics (Cholnoky 1923) that clearly reflect the character of the surface waters. Relatively straight / meandering / discontinuous channels, stagnant / impounded surface waters, steep shore walls, river deltas, spring lands can be distinguished on the first historical military mappings. The modifications of these features are able to be tracked on the further historical military mappings.

The assessment of the original spatial extent of the floodplain: with the help of the historical cartography, historical floodplain wetland areas can be analysed as well. The spatial extent and the changes of areas identified as streamside meadows, reed beds, floodplain forests, indicate which habitat patches were connected to an ecological corridor by the historical dynamics of the stream water.

The assessment of the long profile of the channel: the analysis of the changes of linear landscape features is possible, because of the low accuracy of the historical military mappings. Intensity of the modification of the stream can be concluded from the place and morphological changes of the channel. These historical mappings are regarded as reliable sources of information, as far as the assessment of channel evolution and regulation interventions are concerned. In this study, our intention was to draw consequences based on the mappings, concerning the pre-regulation channel dynamics of the Váli-stream, the characteristics of the streambed, the level of alteration, in order to use this information to define the target conditions of the restoration.

Land use, landscape pattern

The current land use pattern was assessed by topographic maps (1:10000), by Google Maps images, and through the experiences of the field surveys. The effective regional and local spatial plans (Planner T. 2002, 2006; VÁTI 2009) were also considered during the analysis of the developments.

Habitat mapping and spatial analysis

The actual habitat map was prepared between June and October in 2013. The habitats are identified by the National Habitat Classification System (so-called Á-NÉR, see in: Bölöni et al. 2011), because this new concept of vegetation mapping is particularly concerned with the secondary, degraded habitats. The habitat types were recorded along the 11 km long stream section, in 100 to 100 m width. For the estimation of naturalness based habitat quality, the so-called Németh–Seregélyes naturalness system was used: 1 = totally degraded state; 2 = heavily degraded state; 3 = moderately degraded state; 4 = semi-natural state; 5 = natural state, or a state that can be considered as natural (Takács – Molnár 2008).

The spatial analysis of the habitat map was performed with ArcGIS 9.3 and ESRI Patch Analyst 4.2 (Rempel et al. 2008). The landscape indices – namely shape complexity, edge density and number of patches as well as average patch size – can indicate the fragmentation of habitats. Metric definitions used in the landscape composition analysis (from McGarigal – Marks 1994): [Shape metrics]: Mean Patch Size (MPS = Average patch size (ha)); Median Patch Size (MedPS = The middle patch size, or 50th percentile (ha)); Patch Size Standard Deviation (PSSD = Standard Deviation of patch areas (ha)); Patch Size Coefficient of Variance (PSCoV = Coefficient of variation of patches); [Edge metrics]: Total Edge (TE = Perimeter of patches (m)); Edge Density (ED = Amount of edge relative to the landscape area (m/ha)); Mean Patch Edge (MPE = Average amount of edge per patch (m/patch)), [Patch density and size metrics]: Mean Perimeter-Area Ratio (MPAR = Shape Complexity (Sum of each patch perimeter/area ratio divided by number of patches) (m/ha)); Mean Shape Index (MSI = Shape Complexity (MSI is equal to 1 when all patches are circular and it increases with increasing patch shape irregularity)); Area Weighted Mean Shape Index (AWMSI = AWMSI is equal to 1 when all patches are circular and it increases with increasing patch shape irregularity).

3. Results

Historical analysis: determination of the historical / natural course-type and dynamics of Váli-stream in the study area

A stream can be characterized, and divided into sections based on the morphological features, or based on the conditions of the water (discharge, water regime, water quality etc.). According to the registration of the local water authority, the Váli-stream can be classified into three different sections; the entire study area belongs to the upper course section, between the 3 and 53 km points of the river. However, the analysis of the historical maps showed a rather complex picture, concerning stream morphology and course-type. Upper, middle and lower course types, standing waters and a spacious ecological corridor could be identified in the study area in the past, as well.

Beside the contemporary conditions observed on the historical maps, it is clear that water regime has considerably changed through time. The adverse impacts of the water engineering processes on water regime (velocity of the transported water increased) was completed by the karst water table lowering effect of deep minig operation processes (karst waters are fundamental water supplies for the streams in the study area, under the arid climatic conditions). After the development of the wastewater treatment plant in Újbarok, a significant proportion of the water discharge is purified waste water. The results of the historical analysis are discussed in sections.

Analysis of Section 1. (“Felső-malom”, 43+842 - 42+518 rkm)

Military mapping indicates a shift from

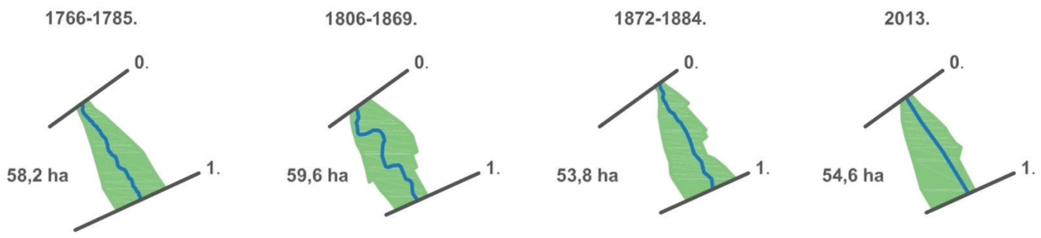

Fig. 3. Historical changes of Section 1. (range of alluvial wetland area marked with green)

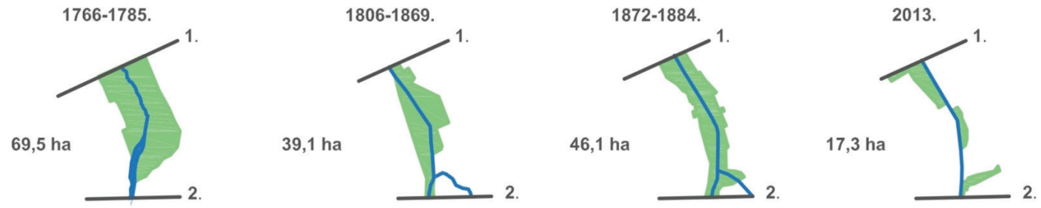

Fig. 4. Historical changes of Section 2. based on historical military mapping (range of alluvial wetland area marked with green)

the upper course type to the middle course type of the Váli-stream. As enters the lowland area, the stream slows down, depositing its sediments in a horn-like shape, forming a wide valley.

Putting the spatial extent of the wetland areas / floodplain into the spotlight it is clear, that no considerable change can be observed (53-60 ha), even looking at the borderlines of these alluvial wetland areas (i.e. floodplain areas and all the wetlands, that are directly influenced by the stream). The stream channel has undergone several changes / alterations, after a meandering character, became regulated, as a result of the establishment of the mill (in the end of the 19th century). The stream channel is situated permanently in the middle of the valley, as it can be experienced currently (see Figure 3.).

Analysis of Section 2. ("Tófenék", "Kenderföldek", 42+518 - 41+196 rkm)

In the second historical military mapping it is represented as a wider valley located on a section above Mount Sinai, full with stagnating water, where – in other eras – smaller water surface or regulated stream appeared. As the stream – on this spot – passes by the border of the vegetable gardens in Felcsút, traditionally, it is the level of 136 m (above Baltic Sea level) that is considered to be the level of the flood protection. This was the altitude, where the railway road, having access to the stream on this section, was built and also this was the border of developed area from the direction of the stream. The analysis of the alluvial wetland areas definitely shows that the territory of the historical ecological corridor has significantly decreased from 70 ha to less than 20 ha.

From the second half of the 19^{th} century, at the border of the former wetland, water was delivered by an artificial channel, the track of which has not been changed since then, after the first engineering works it can be regarded as a constant one (see Figure 4.).

Analysis of Section 3. (inner area of Felcsút, 41+196 - 38+714 rkm)

On the section located right at the toes of Mount Sinai the surveys show a significantly narrowed valley. As a result of the limited space, the bed slope of the stream becomes larger in a natural way, while its water is becoming quicker, dominated by riffles.

Later representations show that steep shores were used for stepping the stream, i.e. to change the vertical track, as well. Earlier, the stream played an active role in the life of the settlement of Felcsút on this section. It was meeting the keen demand on water for

Fig. 5. Historical changes of Section 3. based on historical military mapping (range of alluvial wetland area marked with green)

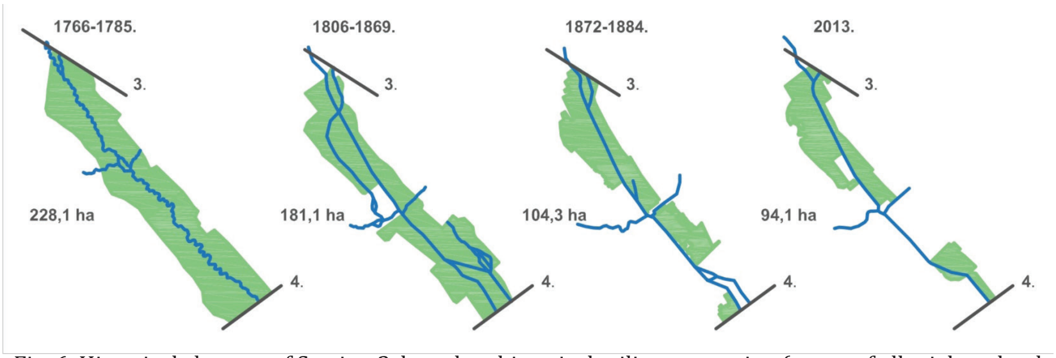

Fig. 6. Historical changes of Section 3. based on historical military mapping (range of alluvial wetland area marked with green)

the local gardening cultures, besides; it drove the mill-wheels located on cross-levees. The new element of present state is the circular embankment of the storm water reservoir, which, in fact, has not caused any changes in the features of the section for lack of licenses and consequently also for that of the actual use.

As against the previous ones, the third section had a limited extent of alluvial wetland areas coupled with high permanency at the same time. Because of the fixed morphology of the valley, there is only a slight change in the long section, as well. The high permanency, however, does not mean that the water bed has not undergone any transformations, since the cross embankments and levees affecting the vertical track have influenced the water runoff as early as from the first half of the 19th Century. In the narrow valley, the closeness of the railway line to the stream-bed is an important factor, especially if the railway will be used again in the future (see Figure 5.).

Analysis of Section 4. ("Felső- and Alsó-rét" in Alcsút, 38+714 - 35+000 rkm)

Under Felcsút to Adony the valley becomes significantly wider with parallel margins (700-800 m width). According to the first historical military mapping in this floodplain, formed by a valley of the same width, Váli-stream passed with continuous meandering roughly in the middle. Later, water-engineering works established one main stream-bed and several anabranches (i.e. these channels divert from the main channel). The anabranches worked on several sections between Alcsútdoboz and Tabajd as mill-channels.

In the fourth section the extent of alluvial wetland areas considerably changed and decreased from 230 ha to 100 ha. Instead of an even meandering it drove the mill wheels into artificial main- and anabranches, and the runoff of its track also changed several times (see Figure 6.).

Land use, landscape pattern

The north-south oriented channel of the Váli-stream is a particularly dominant

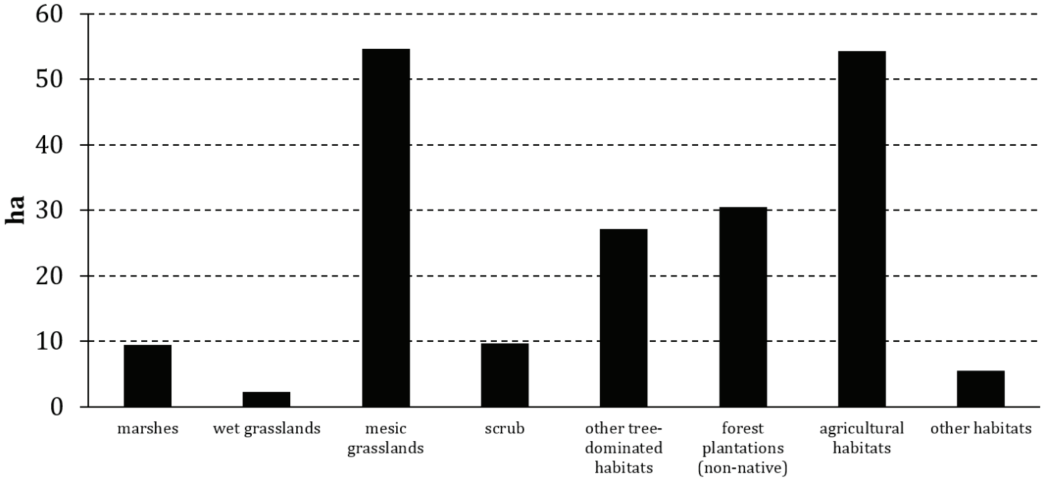

Fig. 7. Main habitat types of Váli-stream

landscape feature, fundamentally determining the landuse pattern of the study area. The settlements were developed in a strip-like shape along the stream, the main streets of the villages are running in parallel with the Váli-stream. This structure is followed by the lower order cart roads in the outskirts, as well. East from Felcsút, crossing the Váli-stream and heading south, west from Alcsútdoboz, and an abandoned railway line is situated.

The larger, spacious and continuous landscape patches are characteristic for the northern part of the study area (Section 1-2.). Grasslands and arable lands are dominating next to Felcsút, on the flat terrain forms in the valley of the stream. Among the arable lands, partly abandoned agricultural works, farm-yards are located. Beside these, smaller patches of forests can be found on the steep slopes of the valley.

On the southern part of the study area (Section 3-4.) the landscape became rather mosaic-like, as a result of the diverse relief and terrain conditions. Smaller forest patches are typical in this region, bordered by various land use forms. Grasslands and arable lands are still dominating the landscape, forming larger patches. However, at the fringes of the settlements and on hillside areas, vineyards, orchards are also characteristic and the transitional form of these are partly used already for residental purposes. These transforming agricultural areas are located scattered in the study area, except for a long, but narrow strip of vegetable gardens along Alcsútdoboz.

Habitat mapping, spatial analysis

Habitat types

In 2013, there were totally 191 separate habitats (i.e. habitat patches) detected in the study area (Váli-stream belonging to Újbarok, Felcsút and Alcsútdoboz settlements), consisting of 28 habitat types and their 23 combinations.

The ratio of the main habitat types is the following (see Figure 7., Table 1.):

1. wet and mesic meadows (29,4%)
2. agricultural habitats (28,1%)
3. non-native afforestation (15,7%)
4. native tree-dominated habitats (14,0%)
5. scrub (5,0%)
6. marshes (4,9%)
7. other habitats (2,8%)

The greatest extent of wet and mesic meadows (mainly hay meadows) and agricultural habitats (extensive and intensive arable fields) in the study areas, covering 57.5% of the total area, indicates significant

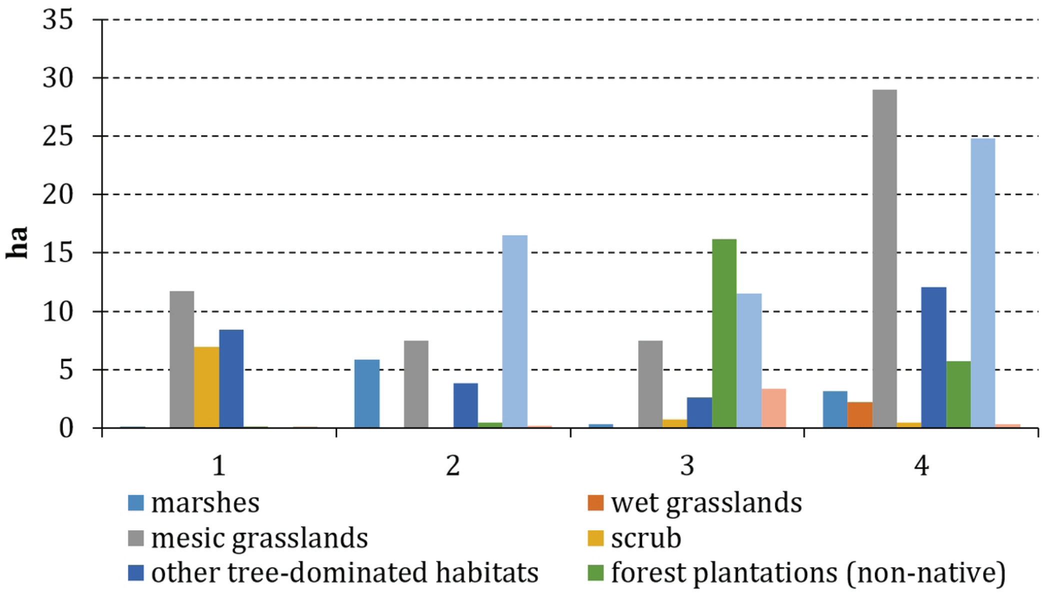

Fig. 8. Main habitat types of the 4 sections along Váli-stream

anthropogenic effects. However, a relatively high proportion of native tree-dominated habitats (scattered trees and pioneer forests) and wet and semi-dry scrub (19%) indicates regeneration processes.

The typical vegetation of 4 sections taken in the historical analysis are characterized as follows (see Figure 8.):

- Section 1 (Felcsút: "Felső-malom"): mesic meadows (11.7 ha), scrub (6.9 ha), native tree-dominated habitats (8.4 ha).
- Section 2 (Felcsút: „Fenék" és „Kend-erföldek"): agricultural habitats (16.5 ha), mesic meadows (7.4 ha), marshes (5.8 ha).
- Section 3 (Felcsút: inner area of village): non-native afforestation (16.2 ha), agricultural habitats (11.5 ha), mesic grasslands (7.4 ha).
- Section 4 (Alcsútdoboz: „Felső- és Alsó-rétek"): wet and mesic meadows (31.2 ha), agricultural habitats (24.8 ha), native tree-dominated habitats (12 ha), non-native forest plantations (5.7 ha).

Based on the above, the habitats of sections 1 and 4 seem to be the least affected by the intensive human activities, namely the traditional meadow management can be observed here. It should be noted, however, the relatively great extent of marshes (reed beds) in the section 2. In the sections 2 and 3 agriculture (intensive farming) and forestry prevails.

Habitat quality, naturalness

Evidently, the so-called "uncharacteristic" habitat types ("OA", "OB", "OC", "RA", "RB") are less natural (naturalness value is 3, i.e. moderately degraded/regenerated state) (Bölöni et al. 2008). These habitats have been strongly affected by human impact, with the agricultural cooperative engaging in intensive farming since the 50s, then individual management since the 90s.

However, the relatively high 8.7% ratio of semi-natural (value 4) habitats (mostly wet and mesic meadows and pioneer forest patches) reflects a traditional agriculture in some regions. Secondary shrub habitats ("P2a", "P2b") that develop after disturbance or abandonment have relatively low (value 2-3) habitat quality. The marshes ("BA", "B1a", "B5") change from heavily degraded (value 2) to semi-natural (value 4) state, depending on the surrounding land use. Among the habitats, the arable fields ("T"), forest plantations and

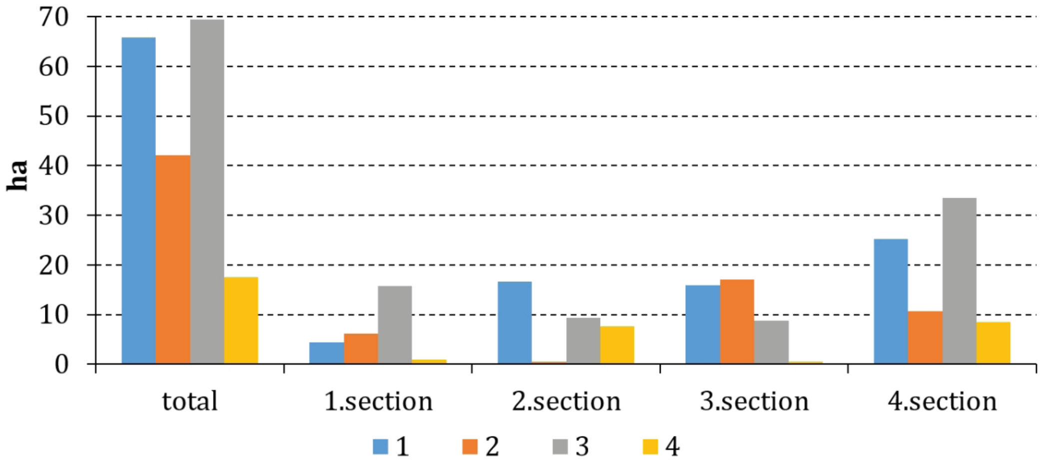

Fig. 9. Vegetation naturalness of 4 sections along Váli-stream (legend: 1= totally degraded state, 2= heavily degraded state, 3= moderately degraded state, 4= semi-natural state)

spontaneous invasive tree stands ("S") are in the worst state from the nature conservation perspective (value 1).

The habitat quality of the 4 sections taken in the historical analysis are characterized as follows (see Figure 9. and 10.):

- Section 1 (Felcsút: "Felső-malom"): mainly moderately degraded/regenerated (58%).
- Section 2 (Felcsút: „Fenék" és „Kenderföldek"): mainly totally degraded (49%), but 22% semi-natural (reed beds and scattered native trees).
- Section 3 (Felcsút: inner area of the village): totally or heavily degraded (78%).
- Section 4 (Alcsútdoboz: „Felső- és Alsórétek"): mainly moderately degraded (43%), but 11% semi-natural (mesic meadows).

Spatial heterogeneity (landscape composition)

Landscape metrics data refer to the measure of habitat patches, i.e. their number, size, densities, shapes etc. Landscape composition investigated in this study is associated with the variety or abundance of each class (habitat types) within the landscape (section) but it does not take into consideration the placement/location of patches within the landscape.

Landscape metrics can be classified either as "structural" metrics, that measures the physical composition or the configuration of the patch mosaic without explicit reference to an ecological process, or "functional" metrics, that explicitly measure landscape pattern in a manner that is functionally relevant to the organism or process under consideration and require additional parameterization prior to their calculation. In this analysis the first ("structural") group of metrics was used.

The spatial heterogeneity ("patch mosaic") of 4 sections taken in the historical analysis is characterized as follows (see Table 2.):

- Section 1 (Felcsút: "Felső-malom", 26.4 ha, 15 habitat types and combinations): number of patches is low (23), Mean Patch Size is moderate (1.15 ha), Edge density is the lowest (424 m/ha), Shape Complexity is low.
- Section 2 (Felcsút: „Fenék" és „Kenderföldek", 34.2 ha, 13 habitat types and combinations): number of patches is low (23), Mean Patch Size is the highest (1.49 ha), Edge density is moderate (504 m/ha), Shape Complexity is the highest.
- Section 3 (Felcsút: inner area of village, 42.2 ha, 23 habitat types and combinations): number of Patches is high (57),

Mean Patch Size is the lowest (0.74), Edge Density is highest (643 m/ha), Shape Complexity is high.

- Section 4 (Alcsútdoboz: „Felső- és Alsó-rétek", 77.7 ha, 27 habitat types and combinations): number of Patches is the highest (62), Mean Patch Size is moderate (1.25), Edge Density is low (487 m/ha), Shape Complexity is high.

Based on the above, the the order of spatial heterogeneity of sections can be interpreted as follows: section 3 > section 4 > section 2 > section 1.

The spatial heterogeneity could be related to the fragmentation, which is an important factor for ecological function. Beyond that, the most serious impact on the ecological function which is responsible for the fragmentation is the barriers (mainly roads, built areas and agricultural land use in the study area).

Table 1. List and area of habitat types of Váli-creek: 28 habitat categories and 23 hybrid habitat categories

Habitat type	Á-NÉR 2011 codes	***Total area (ha)***
Marshes:		**9,46**
1 Eu- and mesotrophic reed beds	B1a, B1a x B5, B1a x P2a	7,62
2 Non-tussock tall-sedge beds	B5, B5 x OD	0,24
3 Fine scale mosaic or zonation of marsh communities	BA	1,60
Rich fens, wet grasslands and tall-herb vegetation:		**2,26**
4 Mesotrophic wet meadows	D34	2,26
Other treeless vegetation:		**55,87**
5 Uncharacteristic wetlands	OA, OA x OD x P2a	0,46
6 Uncharacteristic mesic grasslands	OB, OB x B1a, OB x OF, OB x P2a, OB x P2a x OD, OB x S6	54,20
7 Uncharacteristic dry and semi-dry grasslands	OC	0,40
8 Stands of invasive forbs	OD	0,80
9 Trampled and ruderal vegetation	OG	0,02
Scrub:		**9,73**
10 Wet and mesic pioneer scrub	P2a, P2a x OD	2,42
11 Dry and semi-dry pioneer scrub	P2b, P2b x RA, P2b x S6	7,31
Other tree-dominated habitats:		27,14
12 Parks, botanical gardens, old church-yards	P6	5,63
13 Cutting areas	P8	5,77
14 Scattered native trees or narrow tree lines	RA, RA x B1a, RA x B1a x B5, RA x OA, RA x OB, RA x P2a, RA x P2a x OB, RA x S6, RA x S7	12,46
15 Uncharacteristic or pioneer softwood forests	RB	3,29

Forests and plantations dominated by non-native tree species:		**30,44**
16 Robinia pseudoacacia plantations	S1	17,00
17 Populus x euramericana plantations	S2	1,45
18 Spontaneous stands of non-native tree species	S6, S6 x OC, S6 x OD	3,16
19 Scattered trees or narrow tree lines of non-natives tree species	S7, S7 x P2a x S2	8,84
Agricultural habitats:		**54,30**
20 Annual intensive arable fields	T1	33,51
21 Sowed or fertilized grasslands, sport-grounds	T5	3,61
22 Extensive arable fields	T6	13,49
23 Extensive vineyards and orchards	T8	0,12
24 Gardens	T9	3,57
Other habitats:		**5,50**
25 Farms	U10	0,07
26 Roads and railroads	U11	1,95
27 Villages	U3	2,94
28 Yards, wastelands, dumping grounds	U4	0,54

Table 2. Spatial statistics of the habitat patches of Váli-creek

	Patch Density and Size Metrics			Edge Metrics			Shape Metrics					
	AW-MSI	MSI	MPAR	TE (m)	ED (m/ha)	*MPE (m)*	*MPS (ha)*	*Med-PS*	*PS-CoV*	*PSSD*	*NP*	*CA (ha)*
Total	1,92	1,85	1223,65	104397	536	547	1,01	0,42	160,56	1,63	191	194,7
Section 1.	1,48	1,71	1345,70	11214	424	488	1,15	0,50	115,96	1,33	23	26,4
Section 2.	2,07	2,04	1116,01	17259	504	750	1,49	0,51	129,51	1,93	23	34,2
Section 3.	2,13	1,82	1238,83	27167	643	477	0,74	0,30	207,52	1,54	57	42,2
Section 4.	1,95	1,83	1125,35	37864	487	611	1,25	0,45	149,47	1,87	62	77,7

Metric denotations: Area Weighted Mean Shape Index (AWMSI), Mean Shape Index (MSI) (=1, if all the patches are circle, its value is growing with complexity of the shapes), Mean Perimeter-Area Ratio (MPAR), Total Edge (TE), Edge Density (ED) (=TE/CA), Mean Patch Edge (MPE), Mean Patch Size (MPS), Median Patch Size (MedPS), Patch Size Standard Deviation (PSSD), Patch Size Coefficient of Variance (PSCoV) (=PSSD/MPS), Number of Patches (NP), Class Area (CA)

4. Discussion

Defining an area for potential ecological restoration

The extent of theoretically alluvial wetland areas has been assessed on basis of the legally mandatory local plans. It has been established that no artificial flood protection system was developed on the area concerned and the areas urbanized or to be urbanized – meaning the most relevant limiting factors have not reduced significantly the area of a potential ecological corridor either (see Figure 11.).

Following the historical changes of the range of the stream-bed and that of the habitats along the stream – including the entire sections assessed – it has been found that the streamside habitat patches have decreased significantly despite the constant space available (see Table 3.) This change was not caused by the increased area of the settlement, but rather by the higher dominancy of arable land use forms.

Fig. 10. Vegetation naturalness of Váli-stream (legend: 1= totally degraded state, 2= heavily degraded state, 3= moderately degraded state, 4= semi-natural state)

Target status and style of restoration

The stream-bed restoration primarily aims at improving the ecological condition of the areas along the stream and that of the stream, alike. For the ecological restoration of the currently strongly modified water bodies it is essential to carry out the very interventions which focus on naturally evolved, meandering stream-beds with diversified habitats, or which support their evolution, prior to regulating the stream.

Restoration of the stream and the attached interventions may as well be interpreted as pressures / disturbances, which can induce damages of valuable habitats. Accordingly, restoration is to be put through in a way that considers not only the reference state of the historical analysis, and the current landscape pattern, but having in mind also the location of the affected important habitats.

Actually, it should be decided, whether habitat improvement with slight modification (e.g. applying in-stream measures, supporting natural processes) or complete restoration / reconstruction (at the floodplain scale,

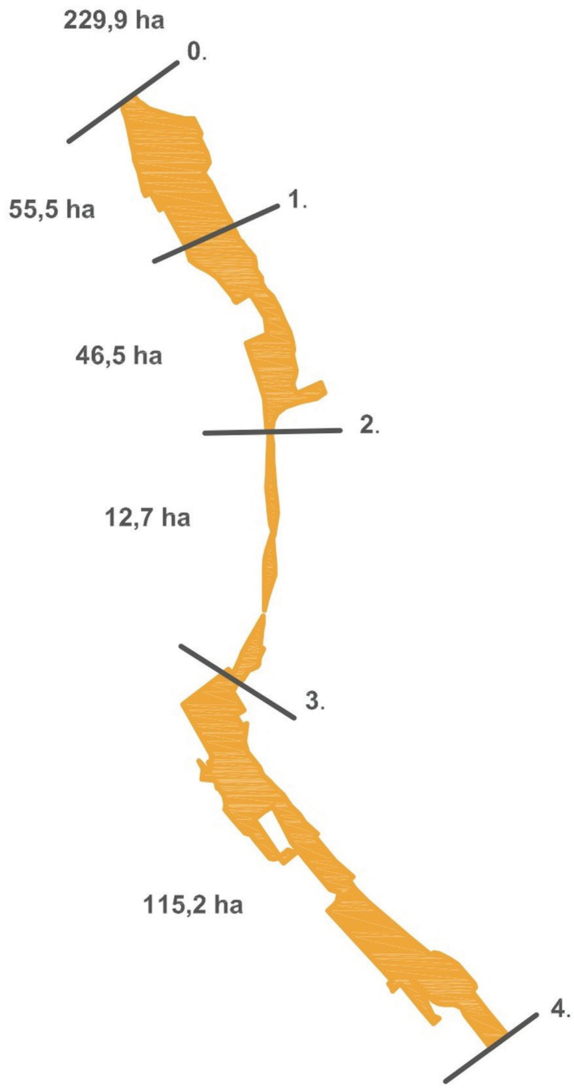

Fig. 11. Extent of the potential area for restoration

Table 3. Changes of the historical ecological corridor

Section	1.historical military mapping (ha)	2. historical military mapping (ha)	3. historical military mapping (ha)	Present (ha)	Extent of the potential are for restoration (ha)	Proportion of potential available area and maximum range of historical ecological corridor
Section 1.	52,8	59,6	53,8	54,6	55,5	93%
Section 2.	69,5	39,1	46,1	17,3	46,5	67%
Section 3.	9,1	16,1	14,1	15,4	12,7	79%
Section 4.	228,1	181,1	104,3	94,1	115,2	50%
Total	359,5	295,9	218,3	181,4	229,9	64%

with intensive engineering interventions) is to be suggested. Should the section at issue have enough restoration potential and smaller changes and maintenance may result in significant results, it is the habitat improvement to be suggested. In this case there is a good chance to restore the dynamics of the stream without developing fixed structures. Should the section at issue have little restoration potential to achieve the target, reconstruction is to be suggested, which, however means significant disturbance in itself. Restoration style and intensity have been defined on the basis of all the assessed factors (see Table 4.).

In the first section, the ecological condition of present habitats should be improved and a wetland has to be developed while using the dynamics of the section-character of the stream. To elaborate the suggestions on the basis of the historical military mappings the natural embankment area generated by the shift of section-character may serve as basis, whereas for full transformation of the stream-bed it is the definition of the potential area of the ecological corridor that gives the guideline. The above is justified by the conditions of the habitat that though the section is not fragmented, space has left for restoration, yet, it is characterised by less near-natural habitats.

In the second section, the ecological condition of the stream and of the present habitats along the stream should be improved, coupled with a moderate increase of the ecological corridor. The moderate interventions are justified by the fact that – on the basis of the historical military mappings – the ecological corridor has significantly narrowed, the track of the present stream-bed is relatively constant, and furthermore the present meadows are regarded as features to be retained.

In the third section, the connection between the settlement and the stream, as well as safe-keeping of the existing ecological values should be ensured during the expected developments. The significant constancy of the historical ecological corridor, full transformation of the present vertical track of the stream-bed, the meaningful historical connection between the stream and the settlement, the strongly fragmented habitats (their diversity also means that there are potential "building blocks") all justify the style of interventions.

In the fourth, southern section, the aerial increase of the ecological corridor and the improvement of the ecological condition of the stream seem to be reasonable. In this case the typical valley morphology, including a significant decrease of the area of the ecological corridor, and full transformation of the present stream-bed determined primarily the style of restoration. On this area mainly meadows are characteristic; further increase

Table 4. Restoration targets, style and intensity

		Section 1.	**Section 2.**	**Section 3.**	**Section 4.**
	River kilometre (rkm)	43+842-42+518	42+518-41+196	41+196-38+714	38+714-35+000
Historical assessment	*Section type*	lower course	middle course	upper course	middle course
	Proportion of potential available area and maximum range of historical ecological corridor	93%	67%	79%	50%
	Level of streambed alteration	significantly altered	moderately altered	moderately altered	significantly altered
Habitat mapping	*Main habitat types*	mesic meadows, scrub, scattered native trees and pioneer forests	agricultural habitats, mesic meadows, marshes	forest plantations, agricultural habitats, mesic meadows	wet and mesic meadows, agricultural habitats, scattered native trees
	Naturalness	mainly moderately degraded (3)	inordinate (1-4)	totally or heavily degraded (1-2)	mainly moderately degraded (3), (meadows: 4)
	Landscape heterogeneity (pattern)	the least heterogeneous	less heterogeneous	the most heterogeneous	less heterogeneous
Suggestions	*Target status*	spacious wetland, sediment deposition	ecotourism, actively maintained meadows	an "attractive" creek, settlement fringe with high ecological and visual quality	ecotourism, actively maintained meadows
	Restoration style / intensity	intensive engineering, reconstruction	slight modification, re-naturalization, habitat improvement, in-stream-measures	intensive engineering in the vertical profile	reconstruction / slight modification, habitat improvement

of meadows, habitat diversity and stability should be preferable.

It can be summarized that it is not only the historical reference condition that determines the possibilities for restoration, but the analysis of the limiting factors is a key issue as well. The extent of the areas available to manage the problems, is generally smaller than that of the earlier floodplains, because the territories – meanwhile developed or to be developed later on – cannot be reckoned with. On the basis of the assessment performed, it can be concluded that the Váli-stream is a typical stream both in compliance with WFD (type "9a") and regarding its restoration possibilities.

The assessment based on the historical analysis, the current landscape pattern and the habitat conditions may be applicable to define the restoration potentials of other similar streams, too. This is justified by the fact that – in the case of most streams – the applied data are available, completed by on-site surveys. A more detailed assessment in the future by extending the analysis could give a more comprehensive picture of the full catchment area.

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