

## DISAPPEARED FEN-MEADOWS HABITAT – IMPORTANT LOCAL HISTORICAL BIOCENTER IN CENTRAL PART OF BRATISLAVA, SLOVAKIA

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### Disappeared fen-meadows habitat – important local historical biocenter in central part of Bratislava, Slovakia

This study focuses on the defunct historical wetland habitat located at the interface of Carpathian and Pannonian phytogeographical regions in what is now central part of Bratislava, Slovakia. S. Lumnitzer in his *Flora Posoniensis* (1791) reported interesting marsh species from the then location „unter dem Pazenhäusel“, such as *Pedicularis palustris*, *Peucedanum palustre*, *Eriophorum angustifolium*, *Dactylorhiza majalis*. Using botanical and geological data, historical maps, field survey and radio-carbon dating, we have reconstructed the location, character and initial area of a historical wetland, evidenced by abovementioned taxa, but also controlling factors which had determined its existence. Human-dependent fen-meadows habitat, probably with a plant community of *Caricetum goodenowii*, began to decline upon draining in 1890s and eventually fell victim to urban development. Palaeoecological record from a small forest wetland – remnant of former marsh at the margin of Horský park (= renowned urban forest) – has documented a relatively young age and co-alluvial character of deposits, although the examined 80 cm deep core extends back to the 17<sup>th</sup> century. In total 727 plant seeds, belonging to at least 44 plant taxa document succession (macrofossil zones MZ 1 – 3) and environmental changes over time.

**Key words:** land use change, fen marsh, *Caricion fuscae*, palaeoecology, Horský park, Bratislava urban area

## INTRODUCTION

The area of Bratislava, national capital of Slovakia with population of about 530 000, lies within both Pannonian and Carpathian phytogeographical regions. Therefore, Greater Bratislava with its 368 km<sup>2</sup> has quite a variable natural environment – the Little Carpathian (Malé Karpaty) Mts. in contact with the Danube River, Danube and Záhorie Lowlands. The flora of the town and its surroundings was scientifically documented as early as the 18th century, prior to urban expansion by Stephan Lumnitzer in his precious work *Flora Posoniensis ...* (1791). Employed as a town's doctor, Lumnitzer dedicated his leisure time to botany. In 1780s he became well familiar with the local conditions. He also paid visits to several nearby locations (Pezinok, Modra, Žitný ostrov, even Lake Neusiedl in Austria).

In his work Lumnitzer documented in total 1 294 plant taxa, out of which 1 030 were spermatophytes and pteridophytes. This number represents up to 80% of all plants suggested to grow in Bratislava (cf. Feráková et al. 1994). The most valuable are the data, where Lumnitzer also mentioned names of specific locations where plants grew (almost 100 different sites). He applied the then used place names across both agrarian and forested country (local names of islands, vineyards, fields,

ravines etc.). Also, different natural and human-made structures in rural country served as important benchmarks to allow explicit identification – water mills, springs, inns, roadside crosses etc. Despite this, identification of some places still remains questionable because it requires thorough knowledge of local historical geography of 18th century Bratislava. Therefore, the work of Lumnitzer is a fountain of knowledge about the status of local flora mainly in the 1780s. Plant composition reported from some locations even allows certain habitats to be reconstructed to some extent. For instance, on Brückenau Island, Lumnitzer listed 16 species of lower plants and 36 taxa of vascular plants (Pišút 2004), for Pečňa Island (Pötschenau, cf. Pišút et al. 2021) he mentioned up to 37 taxa and for the Mill island (Mühl Au) 28 species.

Trustworthy reconstruction must always be based on contemporary data for the studied location (verbal and pictorial sources), but also on knowledge of present-day vegetation. Letz (2000) excellently demonstrated such approach to floristic reconstruction in 18th century suggesting examples of two historical locations, where character of the landscape had been changed completely when compared to the past. First location – the Calvary Hill – was an unvegetated hill with dry xerophytic grasslands on acidic rocks, scrubland, and fields. Since then, the surroundings of the Calvary have developed into a residential quarter with the hilltop overgrown by woods. Second example is the location „unter dem Pazenhäusel“. This must have been an interesting fen-meadows habitat located in what is now a central urban part. Several precious and rare species have grown here, some of them missing from the current flora of Bratislava (Letz 2000).

This study focuses on examining the location and area of former wetlands and evaluates the natural conditions and factors controlling its existence. In addition, we also tried to uncover physical evidence of the former marsh by analysing samples, taken in the field at places to where it had once extended. Research outputs are the synthesis of botanical accounts (Lumnitzer 1791 and Letz 2000), geological, historical (earlier maps and orthophotomaps) and palaeoecological data, supported by radiocarbon dating of biological material.

## MATERIAL AND METHODS

### Study area

The studied area is situated on the SE salients of the Little Carpathian (Malé Karpaty) Mts. in the eastern part of the Lamač Gate (Fig. 1). This tectonically depressed area divides the central massif of the Little Carpathians from a geomorphological subunit of the Devín Carpathians Mts. The south-easternmost part of the latter represents a different subunit called the Bratislava Foothills (mean altitude: 250 m a. s. l.). The area comprises several partial blocks, including Bratislava's Castle Hill. The crests of Horský park, Slavín and the Calvary Hills are slightly inclined towards the NW, grading into a depressed intermontane block. The underlying bedrock is made up of crystalline rocks, with abundant pegmatite dikes (Fig. 1). The upper crust is weathered to a different extent – from weakly weathered and fractured rocks up to completely weathered saprolith with the texture of granitic sand.

In the Quaternary, most of the depressed area was progressively covered by residual granitic colluvium, slopewash and the fluvial deposits of mountain streams.

Basic geological characteristic of the territory is derived from a 1:50 000 series geologic map (Polák et al. 2011), illustrated in Fig. 1.

In this study, we focus on the elongated area with a flat topography extending NW from Horský park, and particularly to ~ 580 m long stretch between the streets Hroboňova and Pri Habánskom mlyne. Horský park (literally: Mountain Park), a renowned urban park, is an entirely wood-covered isolated crest (22 hectares), currently with the status of a Protected Area; hereafter referred to as HP (PA). The largest part of the intermontane depression is the NW-facing shallow slope (2.5 – 7.5°). Elevation decreases from 186 m a. s. l. to 165 m a. s. l. In the past, this historical area was referred to as Hamischgrunt (local medieval German agronym; cf. Fig. 5).

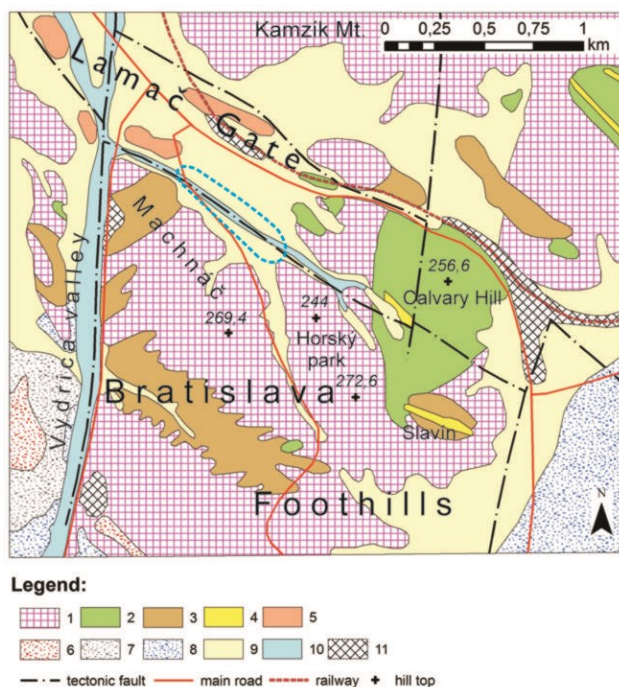


Fig. 1. Simplified geologic map representing the Bratislava Foothills and the eastern part of the Lamač Gate

Geology: 1 – granite, 2 – biotite diorite, 3 – paragneiss, 4 – pegmatite dikes, 5 – conglomerates and sands (younger Badenian), 6 – 8: fluvial deposits, sandy gravels of terrace accumulations: 6 – higher terraces, covered with loess, colluvial and slopewash deposits (Mindel glacial stage), 7 – middle terraces, overlain with loess and colluvium (Riss), 8 – low terrace, bed accumulation (Würm), 9 – sandy to loamy gravels with rock fragments (regolith) and slopewash deposits, 10 – alluvial sediments (Holocene loams), 11 – anthropogenic material (deposits).

The local climate is characterised by a mean annual temperature of 9.5 °C and mean annual precipitation below 661 mm. The coldest month is January (- 1.1 to 2.0 °C), the warmest is July (19.3 – 21.0 °C). In contrast with the past, the urban heat-island effect results in the temperature increase of 1.0 – 1.5 °C in the city compared with the surrounding area. Prevailing direction of winds is from the NE (Feráková and Jarolímek 2011).

In terms of hydrologic conditions, the area of this study includes two small rivulets along the footslopes of the HP, which are important for permanent supplying of the depression by water. They converge below the crest of HP. Whereas both may have become almost dry in warm summers, the brook in the section downstream from their confluence (today canalised) probably had low, but a permanent discharge in the past. The brook flowed along the NE footslopes of Machnáč to enter the Vydrlica creek. A northern rivulet was also replenished by a permanent spring (medieval Thomasbrunn, Thomas's Spring – Fig. 4). In the past, the depressed block must have also been receiving a runoff from long slopes of the Kamzík Mt. However, this component it hard to ascertain since a position of possible local footslope streams is not known and also due to major terrain changes that occurred from the 19th century onward (construction of a railway tunnel etc.).

#### Sediment sampling and palaeoecological analysis

Soil sediments at the waterlogged forest (core MF-1) in HP (Fig. 7) were sampled using a Russian Peat Corer. Initially, a core 80 cm deep was successfully taken for pollen analysis. However, repeated cores in the close vicinity of the first one failed to reach the same depth. Due to a relatively young age of deposits, pollen analysis was eventually not carried out. Since both pollen- and macrofossil profiles had similar depositional layers, we used samples from the initial core (55 – 80 cm) as a supplementary source for both macrofossil analysis and radiocarbon dating, instead. The sediment core was subsequently subdivided into 21 samples with irregular intervals of 1 – 7 cm respecting layer boundaries (of respective weight between 24 and 107 g – Fig. 8).

#### Macrofossils and anthropogenic artefacts

Each sample of sediment was soaked in distilled water with 3%  $H_2O_2$  and left covered for ~ 24 hours. Afterwards the material was wet-sieved (mesh  $\phi$  0.25 mm). All eco- and artifacts were picked. Upon drying, plant diaspores were determined under a stereoscopic microscope with 2 – 45  $\times$  magnification, with the aid of atlases (Cappers et al. 2006, Velichkevych and Zastawniak 2006) and also checked against the reference collection at the Faculty of Natural Sciences (Comenius University). Findings were evaluated and classified by numbers and species related to respective sample depth. Plant macrofossil diagram was arbitrarily divided into zones according to changes in plant spectra. Outputs of geological survey and palaeoecological analysis are presented using Strater and Polpal softwares (Walanus and Nalepka 1999).

#### Radiocarbon dating

In total 4 samples of biological material (*Alnus glutinosa* seeds) were radiocarbon dated at the Centre for Applied Isotope Studies, University of Georgia (Athens, USA) by AMS method. For calibration of  $^{14}C$  dates the IntCal20 calibration with NHZ1 and Oxcal v. 4.4.4 were used, using atmospheric data in Hua et al. (2013) for the period 1950 – 2010 and in Reimer et al. (2020) for 0 – 50 000 years cal BP. Depth-age model was not constructed due to relatively young ages.

#### Vegetation survey

To better understand the palaeoecological data, we have also studied the current local vegetation of the forested wetland in Horský park PA on 23rd August 2013.

Besides carrying out a floristic survey, three phytosociological relevés were taken by standard field method (Braun-Blanquet 1964), first in the coring site itself and additional two along a catena of the footslope sites. On 12th August 2021 the area was revisited for a fast control check. Plant nomenclature follows Marhold and Hindák (1998).

## RESULTS

### Georelief, local geological conditions and original soils

As the analysis of the local relief conditions shows, below the NW margin of the HP slope gradient abruptly falls to some 2,5 ° and below. This led to a retarded flow of groundwaters from this intermontane depression. Its lowermost parts with W and SW slope aspect used to be shaded by adjacent slopes of Machnáč range in some parts of a season, which could support cooler and wetter conditions at the base of the slope.

In addition to a knowledge of a geologic map 1:50 000 (Polák et. al. 2011), more complete picture of the studied area between the Brnianska street and the massif of Machnáč was retrieved from several earlier geological surveys from the period 1955 – 2010, which are stored in the Geofond archives (State Geological Institute of D. Štúr, Bratislava). For this study, we have revised the data of 9 selected borehole cores, which are listed in Table 1. We have used data from surveys ran on various occasions, particularly from one at the Bohúňova street 27, with references to several earlier geological tasks therein (Brhlovič 2008). The visualised data from selected boreholes with a common legend are presented in Fig. 2.

**Tab. 1. Data on selected geological boreholes in the study area**

| Borehole core – original reference code | Borehole – code for this study | Elevation meters a. s. l. | Object / Purpose / Street                     | Source                             |
|---|--------------------------------|---------------------------|---|------------------------------------|
| TH-1                                    | TH-1                           | 186.85                    | Hroboňova street, trolleybus depot and garage | Vlasková and Pisoň (1991)          |
| V-1                                     | B-1                            | 179.76                    | Bohúňova street14 and 24                      | Vlasko (2010)                      |
| V-3                                     | B-3                            | 178.36                    | Bohúňova street14 and 24                      | Vlasko (2010)                      |
| S-4                                     | Ú-4                            | 186.57                    | Child health center, Úprkova street           | Gerháth (1954) in Brhlovič (2008)  |
| VK-4                                    | K-4                            | 184.56                    | Kubányho street17 – 19                        | Brhlovič (2008) in Brhlovič (2008) |
| ZS-3                                    | ZS-3                           | 173.80                    | Refuse collection yard, Lovinského street     | Eisner (1977) in Brhlovič (2008)   |
| S-4                                     | KZ-4                           | 176.70                    | Sewer collector line, A – west                | Volek (1961) in Brhlovič (2008)    |
|   | P-2                            | 170.90                    | Post office, Lovinského street                | Volek (1961) in Brhlovič (2008)    |
| S-4                                     | D-4                            | 177.17                    | Primary school, Dubová street                 | Mikuláš (1955) in Brhlovič (2008)  |

Depressed basin downhill of the HP was initially covered by Neogene deposits. Marine and lacustrine sands and clays were later eroded, and the denuded area was progressively infilled with regolith and slopewash deposits. In the Quaternary, col-

luvial and also alluvial sediments of the mountain stream (in the valley bottom) were deposited (Fig. 1). Basal part of the depression is filled with completely decomposed rock or granitic rock fragments, overlain by slopewash loamy to clayey gravels with fragments of rocks up to 4 – 15 cm. At the bottom of the valley itself (boreholes B-3, K-4, ZS-3, KZ-4), fluvial deposits of the mountain stream prevail. They are mainly represented by brown to grey sandy loams, loamy sands with bodies of clayey gravel with granitoid rock fragments. Fine-textured sediments may be primarily of eolian origin – outwashed bodies of decalcified loess. However, neither the possibility that at least part of them may represent leftovers of Neogene sands and muds must not be entirely ruled out (cf. Vlasko 2010).

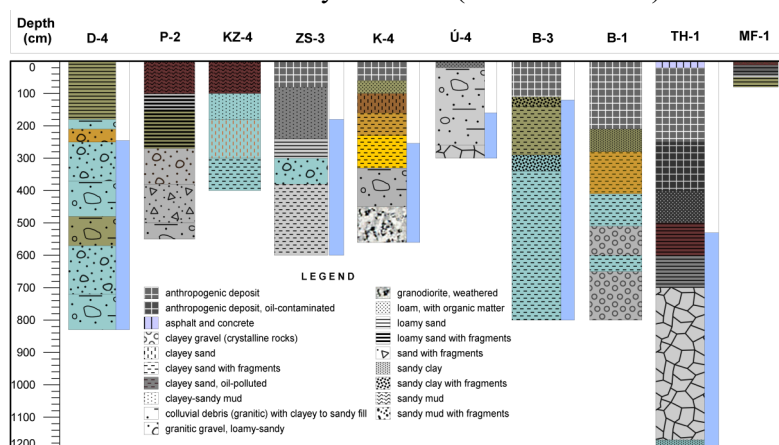


Fig. 2. Visualised data of the earlier geological drillings in wider examined area with inserted profile MF-1 (this study)

Borehole cores aligned down valley (right to left).

On the surface, anthropogenic materials occur often, containing fragments of human activity – charcoal cinder, gravel, building rubble, glass, pot shards etc. Point contamination with oil also occurs (borehole TH-1 – Vlasková and Pisoň 1991).

Finer fluvial and co-alluvial deposits on the valley bottom and the footslopes in places form layers of lower permeability or even an aquitard, resulting in a perched water table. This, coupled with a lower slope gradient determined a retarded runoff and high groundwater level at the lowermost elevations. There was water ponding at the surface not only after snowmelt or heavy rains, but the site has been permanently waterlogged even in dry season as a result of deforestation. This resulted in the formation of a humic horizon with higher content of weakly decomposed organic matter (= gleyic colour pattern, reducing conditions, stagnic colour pattern and/or histic horizon; cf. USS Working Group WRB 2015). Upon partial drainage and urban development, the uppermost layers may have undergone mineralisation. Even so, the groundwater level still remains comparatively high in places since basements of some buildings have formed an obstacle for its free flow.

We suggest that the borehole cores P-2 a KZ-4 give some idea of initial hydric soils and position of a capillary fringe in the past (Fig. 2). They illustrate up to 80 cm thick topsoil layer of dark, humic earth (= mineralised histic horizon). Although

our knowledge of soilscape in the studied area in a pre-developmental period is scarce, a valley floor could have been originally covered by *histic / fluvic Gleysols* and *histic Fluvisols*. Along a footslope (= in the belt between current streets Lovinského and Bohúňova – Fig. 7) they may have graded into the *histic Stagnosols* (IUSS Working Group WRB 2015). In higher uphill zone with thinner regolith, they could have been replaced by *stagnic, endogleyic* to haplic *Cambisols*, eventually *Regosols* (both *skeletal* in places). However, due to the slope conditions, co-alluvial material and mineral slopewash the presence of „pure“ *histosols* is not to be anticipated neither in the lowermost elevations.

#### Historical wetland site in the context of local geographical conditions in the 18th century

According to accounts of S. Lumnitzer, there were wet meadows with a number of interesting plant species located „downhill the Bud House“ (*unter dem Pazenhäusel*) in the 1780s. „Bud“ House (German: *Pazenhäusel*; Slovak: *Púčkový dom*; Hungarian: *Bimbóház*; hereafter referred to as BH) was the proper name of the premises (inn) standing by the current Búdkova road (48° 09' 12.82" N, 17° 05' 28.25" E). Initially, along a trail leading outwards from the town (Kozia brána, Goat's Gate) towards NW, in the 18th century, first inns were erected for needs of walking townsmen, where they could rest, have food and drink. In the 1780s only one such establishment existed. Later on, additional 3 more inns were built (Figs. 3 and 4). Occupants of the town were heading either towards Mary's Spa (*Marienbad*), Calvary Hill (*Calvariberg*), or into a nearby wood. Being known as a *Studentenwald* „Student's wood“ since the mid-19th century, this isolated forest has developed into the current urban wood of Horský park PA. Later on, the BHs also provided a short-term lodging – mainly BH no. 3, being the largest establishment of its kind.

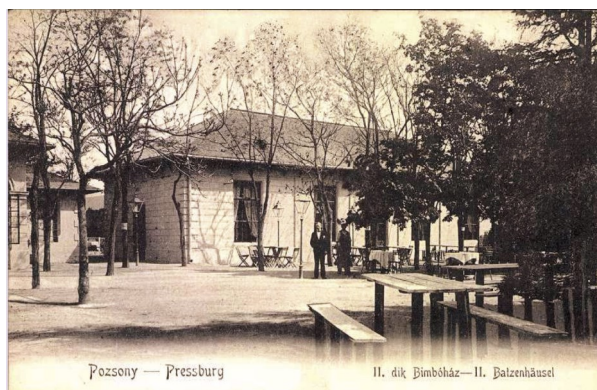


Fig. 3. Bud House – *Pazenhäusel* n. 2 on the historical postcard

Source: Hungaricana (Hungaricana Cultural Heritage Portal), Gallery.

There are fault valleys on either side of HP to divide it from the blocks of Machnáč and Slavín. A wet habitat could have only extended downstream of the point where two rivulets from both valleys converge. Here, at the foot slopes of HP, the area opens into an intramontane depression (Fig. 4).



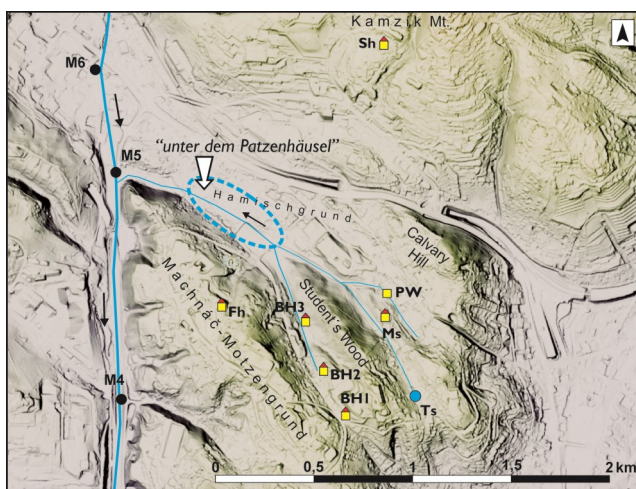


Fig. 4. The historical location of fen-meadows habitat next to the Horský park and recreation places of townsmen in the 18<sup>th</sup> – 19<sup>th</sup> century

Explanations: Bh: Bud Houses (1 – 3 ); M 4 – 6: mills on Vydrice brook; M5 – Mr. Klobušický's Mill; Ts – Thomas's Spring; Ms – Mary's Spa, Fh – Friedliche Hütte (*Friendly Cottage*), Sh – Strohütte (*Straw Cottage*), PW – Prüger-Wallner garden.  
Background DEM: Geodetic and Cartographic Institute, Bratislava.

On the opposite (NW) side, the swamp could have extended to about the location of the current street „Pri Habánskom mlyne“. Here a brook from HP entered only a 70 m wide “funnel” between the elevated knoll and the NW salient of Machnác. Next to the former Mill no. 5 it entered the Vydrice creek (Fig. 4). In second half of the 18th century, this mill belonged to Mr. Klobušický. The narrow alluvial strip was also used as meadows. However, this lowermost section of the rivulet was most probably already a different site, not matching location “*unter dem Pazenhäusel*”. The site would be certainly pinpointed by Lumnitzer simply using the Mill no. 5 as an important benchmark. This can be assumed by species *Hieracium pilosella*, which was growing „in moist grassy places alongside a footpath at the mill of Klobušický“ (Lumnitzer 1791, p. 345).

#### Wetland meadow habitat based on the data of S. Lumnitzer

*Flora Posoniensis* reports in total 20 (*sensu lato*) or at least 16 (*sensu stricto*) species to characterise the distinctive waterlogged meadow habitat situated in the then location „downhill of the BH“ (*unter dem Pazenhäusel* / *Pazenhäusl*). In this area, moist to wet meadows (in Latin: *in pratis udis / humidis*) existed, as well as somewhat moist meadows (*in pratis humidiusculis*), and / or swampy meadows (*in pratis paludosis*). Due to waterlogging, initial peaty layers formed in the soil. This is evidenced indirectly by ecological requirements of the specific species (= *Eriophorum angustifolium*, *Pedicularis palustris*, *Peucedanum palustre*). In the case of two species, botanists also added notes to their abundance. So, *Cirsium palustre* was frequently found here (*frequens*), *Linum catharticum* was abundant (*copiose*). Summary checklist of species reported from wet site NW from BH is summarised in Tab. 2.



**Tab. 2. List of species reported by Lumnitzer from the location “unter dem Pazenhäusel”**

| Original taxon name<br>(Lumnitzer 1791) | Current species name<br>(alphabetically) | Page      | Original description<br>of plant occurrence:                    | Endangerment<br>status<br>(Letz 2000) |
|---|--|-----------|---|---------------------------------------|
| <i>Carduus palustris</i>                | <i>Cirsium palustre</i>                  | 358       | <i>Unter dem Pazenhäusel frequens.</i>                          | Ms?                                   |
| <i>Orchis latifolia</i>                 | <i>Dactylorhiza majalis</i>              | 402       | <i>In pratis paludosis unter dem Pazenhäusel.</i>               | E, R                                  |
|   | <i>Dianthus deltoides</i>                | 175       | <i>... in humidis unter dem Pazenhäusel.</i>                    |                                       |
|   | <i>Epilobium palustre</i>                | 159 – 160 | <i>In pratis paludosis et fossis unter dem Pazenhäusel.</i>     |                                       |
| <i>Eriophorum polystachion</i>          | <i>Eriophorum angustifolium</i>          | 25        | <i>In pratis vdis unter dem Pazenhäusel...</i>                  | Ex                                    |
| <i>Euphrasia officinalis</i>            | <i>Euphrasia rostkoviana</i>             | 259       | <i>In pratis humidiusculis unter dem Pazenhäusel, alibique.</i> |                                       |
| <i>Spiraea ulmaria</i>                  | <i>Filipendula ulmaria</i>               | 206       | <i>In saliceto unter dem Pazenhäusel.</i>                       |                                       |
|   | <i>Gratiola officinalis</i>              | 9.10      | <i>In vdis pratis unter dem Pazenhäusel.</i>                    | V+                                    |
|   | <i>Iris pseudacorus</i>                  | 19        | <i>In vdis unter dem Pazenhäusel,...</i>                        |                                       |
|   | <i>Laserpitium prutenicum</i>            | 112       | <i>In pratis humidis unter dem Pazenhäusel.</i>                 | Ms                                    |
|   | <i>Linum catharticum</i>                 | 131 – 132 | <i>In pratis humidis unter dem Pazenhäusel copiose.</i>         |                                       |
|   | <i>Lythrum salicaria</i>                 | 190       | <i>... copiose in vdis unter dem Pazenhäusel.</i>               |                                       |
|   | <i>Molinia arundinacea</i>               | 36        | <i>In pratis vdis unter dem Pazenhäusel, ...</i>                | Ms                                    |
|   | <i>Pedicularis palustris</i>             | 262       | <i>In prato paludoso unter dem Pazenhäusel.</i>                 | Ms                                    |
| <i>Selinum palustre</i>                 | <i>Peucedanum palustre</i>               | 109       | <i>In pratis paludosis unter dem Pazenhäusel.</i>               | V                                     |
|   | <i>Sanguisorba officinalis</i>           | 64        | <i>... in pratis vdis unter dem Pazenhäusel.</i>                |                                       |
|   | <i>Scirpus sylvaticus</i>                | 25        | <i>In pratis vdis unter dem Pazenhäusel...</i>                  |                                       |
| <i>Scabiosa succisa</i>                 | <i>Succisa pratensis</i>                 | 54 – 55   | <i>... in pratis vdis unter dem Pazenhäusel.</i>                | V                                     |
|   | <i>Scorzonera humilis</i>                | 335 – 336 | <i>In pratis humidiusculis unter dem Pazenhäusel rara.</i>      | Ex                                    |
|   | <i>Valeriana dioica</i>                  | 16        | <i>In pratis vdis, unter dem Pazenhäusel.</i>                   | E                                     |

Note: R – rare, V+ – vulnerable or more threatened, Ms – missing species, E – endangered, V – vulnerable, Ex – extinct from Bratislava (current endangerment status according to Letz 2000).

General conditions of the examined deforested area are also illustrated by relevant data for some additional species. For instance, *Filipendula ulmaria* was growing in a willow wood downhill of BH (Tab. 2). Most probably Lumnitzer pointed out a secondary wood fragment next to the wet meadows. Upslope, wet meadows probably graded into more mesophilous, even dry meadows and pasture. Short note at the species *Statice armeria* implies this (*In pratis et pascuis siccis unter dem Pazenhäusel ...* – Lumnitzer 1791, p. 129).

Location „*In pratis vdis unter dem Pazenhäusel*“ is also given by Lumnitzer for a species *Anemone nemorosa* (p. 224). Here, the habitat was erroneously defined. *A. nemorosa*, typical plant of forest floor, could have grown downhill of BH, but in the forest, more specifically in the area of the present-day Horský park, where it is still commonplace (Reháčková 2009).

Along with additional clues in the hilly zone of the town, such as Thomas's Spring, Holy Spring (*Heiligenbrunn*), Friendly Cottage or Calvary Hill, Lumnitzer used the BH as an important benchmark to give a location for additional 8 plant species – which grew in a close proximity to it, either downhill or uphill from the BH (*Ranunculus auricomus*, *Lonicera caprifolium*, *Allium oleraceum*, *Himantoglossum hircinum*, *Petrorhagia prolifera*, *Agrimonia eupatoria*, *Lathyrus vernus* and *Centaurea phrygia*).

### Past grasslands on historical maps

Pictorial data of historical maps and plans coupled with topographic relief confirm that the examined habitat extended towards SE as far as NW footslopes of HP. In 1860s (map reference 1 in the list) a narrow strip of grasslands reached as far as Mary's Spa, i.e. approximately to the current Nekrasovova street (cf. Mered'a and Letz 2021). It was getting wider at the end of HP, being also cut into by two strips of cornfields. Shape of the grasslands was irregular in 1870 (map ref. 2) and they almost reached the present-day Dubová street. To more precisely ascertain the time when the area had been drained, a cadastral map is of key importance (ref. no. 3). As shown on the map, shortly before 1896 a brook which fed the local wetland was bypassed by an artificial canal at least on the 200 meters long stretch downhill of HP (Fig. 5). Simultaneously, a new canal was dug perpendicular to the latter. This canal captured part of the slope runoff from the Kamzík Mt. massif. By 1900, the grassland area seemed to be more compact and larger than in 1870 (ref. no. 4). After 1918 the whole area of the historical Hamischgrund has been progressively developed and transformed mainly into streets with detached houses. Until then, initial meadows remained reduced only to a narrow strip along the brook between Búdškova road and a newly created Bohúňova street (Fig. 6).

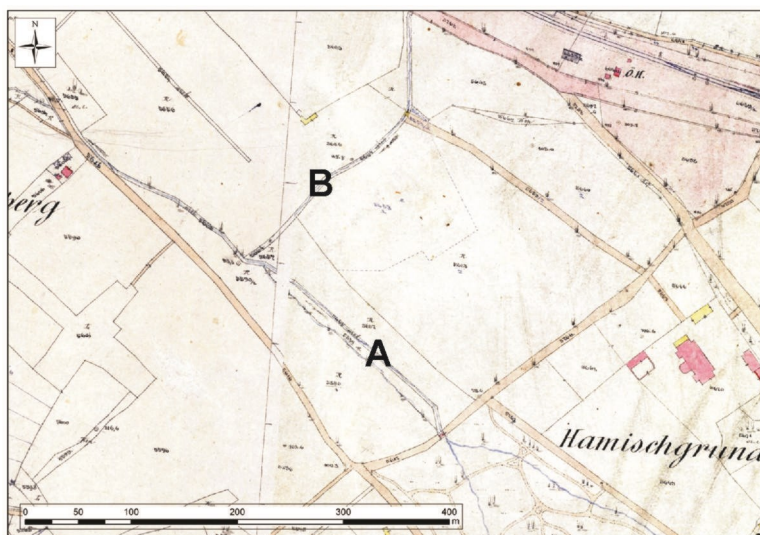


Fig. 5. Cadastral map (cut section rectified to the S-JTSK system) shows a canalised section of a rivulet to drain the area shortly before 1896

(A) Concurrently, additional canal (B) was dug to carry slope waters from the Kamzík massif into the brook.

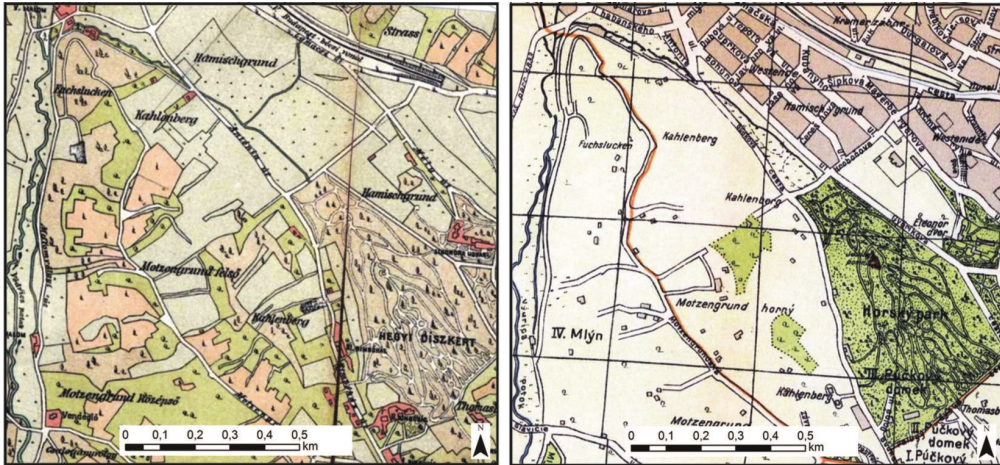


Fig. 6. Progressive urban development of the examined area in early 20<sup>th</sup> century

Left: 1900 plan (reference no. 4). Right 1920s plan (ref. no. 5).

Note: both situations have been rectified to the national coordinate system S-JTSK.

Last remnant of the former meadows (probably represented by degraded mesophilous grasslands) existed along the rectified brooklet in between the Lovinského, Bohúňova and Hroboňova streets (Fig. 7). Only after 1950 the premises of trolley-bus depot next to Hroboňova street were constructed and the rest of the area was parcelled out for individual houses.

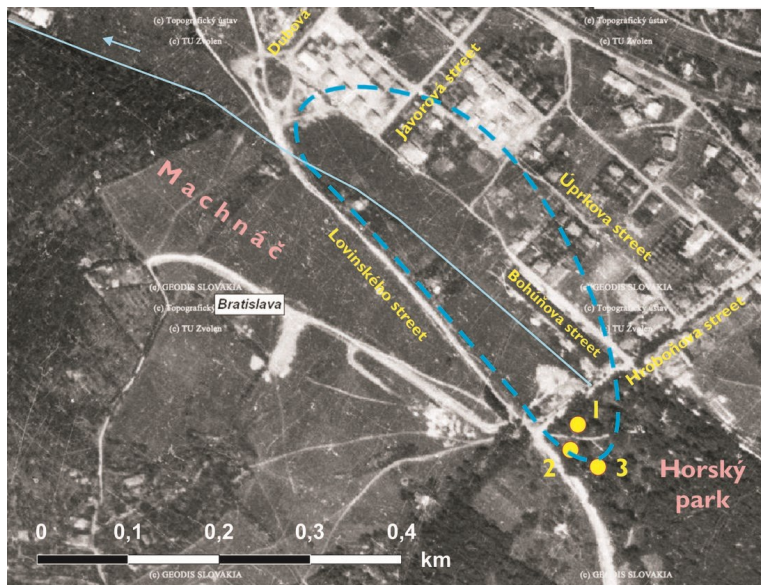


Fig. 7. Situation in 1950 according to historical orthophotomap

Blue dotted line: suggested fen-meadows habitat. Yellow dots: phytosociological relevés.

## Horský park PA wetland site – macrofossil record (MF-1)

Coring site was placed into the waterlogged area in the NW edge of the Horský park PA (48° 08' 6,7" N, 17° 04' 46,6" E). It is situated in the center of phytosociological relevée no. 1; Fig. 10). It was sampled and described on the 12th August 2013.

*Lithology of the profile* (Tab. 2): alternating layers of sandy loams and loamy sands with irregular admixture of dark organic material. Uppermost 14 cm is made of friable black humic earth, beneath with alternating sandy layers with redoximorphic features. In 20 – 42 cm there is ± homogenous layer of dark loamy sand with indistinct veneers. The subsoil was made by grey (42 – 50 cm) and brown-grey loamy sand (50 – 80 cm) with single gravel pebbles and granite fragments < 2 cm. Below 10 cm the soil was saturated with water (moist to wet). According to WRB classification, the deposits, mainly in their upper part, meet the criteria for colluvic material (cf. IUSS Working Group, 2015). Within this classification, the soil can be classified as a *fluvic Gleysol* (*humic, colluvic, arenic*).

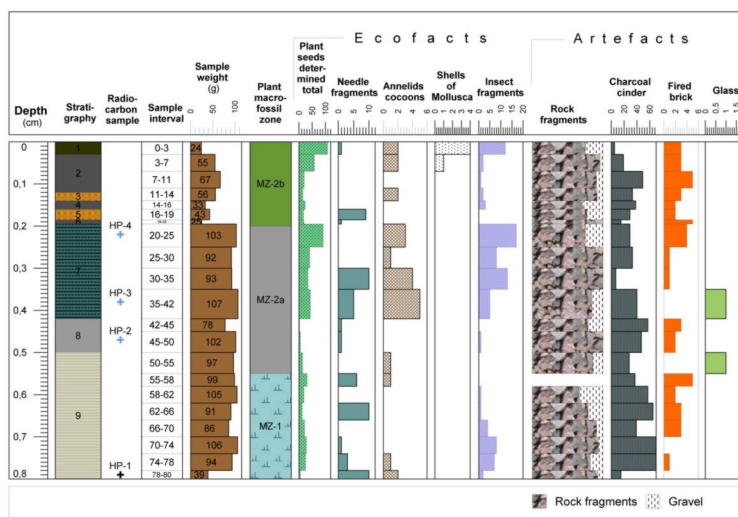


Fig. 8. Lithology, basic morphological parameters, sampling intervals, sample weight and plant macrofossil zones in the profile MF-1

Contents of different eco- and artefacts are given in absolute numbers of specimens.

## Chronology

Radiocarbon data show the lowermost part of the profile likely dates back to the 18th century. Calibrated age of the dated alder seed (sample HP-2013-1) with 95.4% probability falls between 1655 and 1927 calAD, most probably (59.2 %) in the interval between 1733 – 1805 calAD (median: 1767 calAD). However, even earlier calibrated age (1655 – 1685 calAD) is also possible, although with a lower probability (25.4%). In contrast, additional three radiocarbon dates related to macrofossil zone MZ-2 have been determined to be of modern age, i. e. before 1950 AD. More detailed calibration (cf. Hua et al. 2013) has shown the AMS-dated



*Alnus glutinosa* seeds of samples HP-2013-2 to 4 fall, with 95.4% probability, into the period between late 1950s to mid-1980s (Tab. 3). This data also indicates a possible hiatus in sediment accumulation, probably associated with the sediment depth of 50 – 55 cm (approximate interface of MZ-1 and MZ-2; see Fig. 9).

**Tab. 3. Radiocarbon ages of biological samples (achenes of *Alnus glutinosa*)**

| UGAMS# | Sample ID | Depth (cm) | $\delta^{13}\text{C}$ , ‰ | $^{14}\text{C}$ age, years BP | Calibrated yr. AD (95,4%) |
|--------|-----------|------------|---------------------------|-------------------------------|---------------------------|
| 15530  | HP-2013-4 | 22         | -28.6                     | modern*                       | 1959.16 – 1987.13         |
| 15529  | HP-2013-3 | 38         | -27.6                     | modern                        | 1962.21 – 1979.00         |
| 15528  | HP-2013-2 | 47         | -31.0                     | modern                        | 1962.94 – 1974.88         |
| 15527  | HP-2013-1 | 79         | -26.1                     | 200                           | 1655 – 1927               |

#### Plant macrofossils, additional ecofacts and anthropic artefacts

Within ecofacts, total of 727 plants seeds have been retrieved from the 80 cm deep profile. Furthermore, it contained bud scales, needles, remnants of plant tissues and wood fragments. At least 44 plant taxa were determined either into family, genus or down to a species level. In addition to 9 woody plants, numerous herb species, mostly from family of Cyperaceae, Polygonaceae, Caryophyllaceae, Poaceae, Ranunculaceae, Chenopodiaceae, Lamiaceae and some others have been documented. The plants are represented by wet tolerant, meadow species, but also by ruderal taxa of anthropogenically disturbed grounds. The recorded species are largely nitrophilous. Based on the seed abundance and diversity in individual sediment layers, the examined profile can be subdivided into three macrofossil zones as follows:

*Zone MZ-1* (55 – 80 cm) captured the earliest stage in the site evolution (mainly in the 19th century, possibly extending back to the late 17th century). Plant macrofossils suggest  $\pm$  open habitat under anthropogenic disturbances near a small rivulet with a broken canopy stand or solitary alder trees (with some *Betula pendula* also to be found nearby), concurrently representing margin of a wet meadow. Shrubs were only represented by seeds of *Sambucus nigra*. Species growing in a field layer were marsh plants from Cyperaceae family – *Scirpus sylvaticus*, *Isolepis setacea* and sedges (*Carex* typ *otrubae* / *vulpina*, *C. remota*), wet tolerant grass *Glyceria* cf. *declinata* and taxa from Polygonaceae family: *Persicaria hydropiper*, *P. mitis* (sporadically *P. aviculare* agg. – trampling) and *Rumex* (at least 2 species). Seeds of *Stellaria media* agg. complete a knowledge of ruderalised vegetation, most probably belonging to *S. ruderalis* (or *S. neglecta*; cf. Lepší et. al. 2019). The following meadow species were present – partly also in the next zone: *Ranunculus acris*, *R. repens*, also *Ajuga reptans* and *Lychnis flos-cuculi*. The local site was markedly more open than today, with lower portion of nitrophilous plants, compared to MZ-3.

*Zone MZ-2* (20 – 55 cm, ~ late 1950s – 1980s) follows an evident hiatus in paleorecord. Number of seeds in the samples increased  $\pm$  twofold in this zone, particularly from 42 cm up-section, reaching a first peak in the profile in 30 – 35 cm.

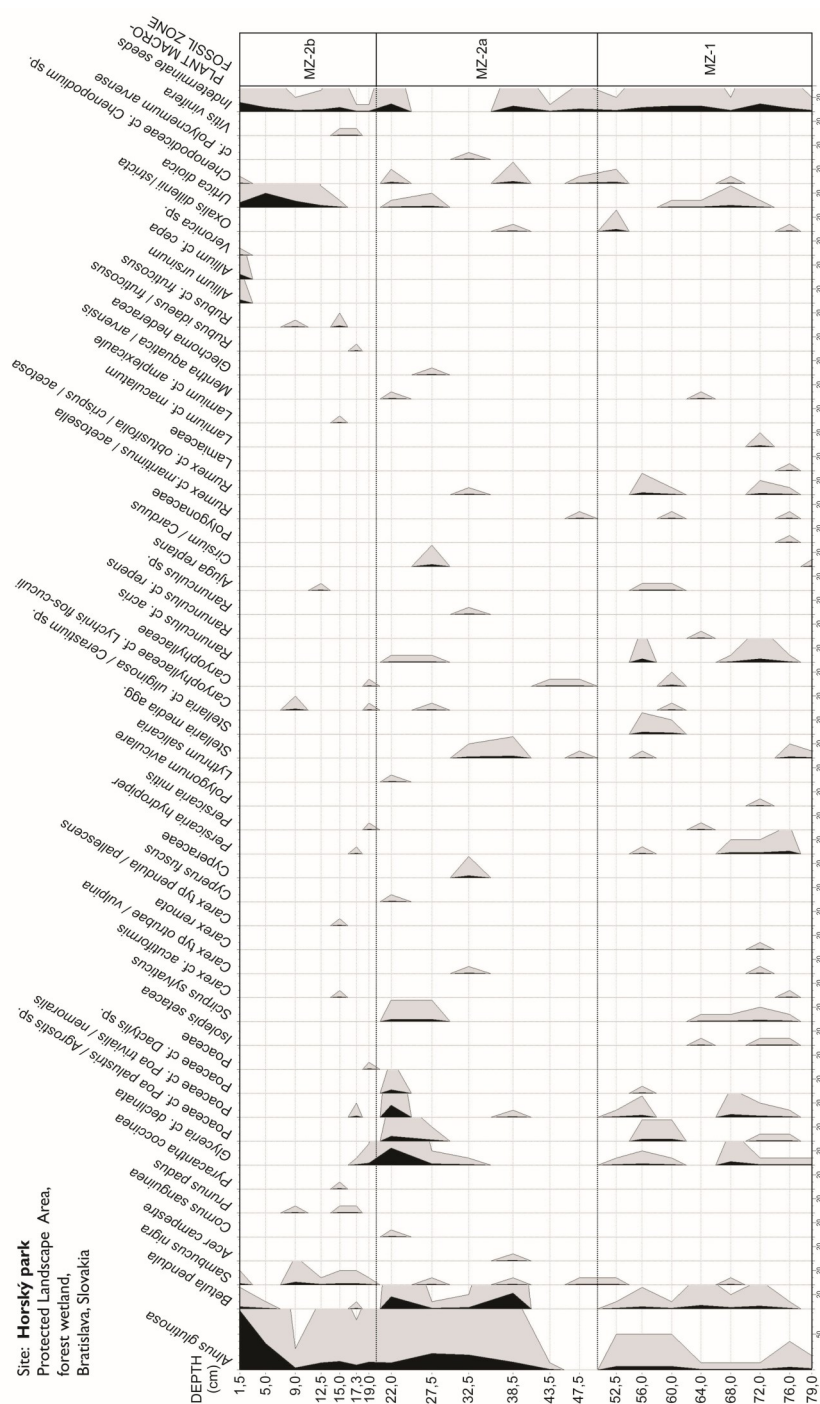


Fig. 9. Horský park PA, core MF-1, plant macrofossil diagram (plant species in respective layers, given in absolute numbers of seeds)



The site remained in part open (*Ranunculus* sp., *Mentha aquatica* / *arvensis*), but forest environment was progressively developing (seed of *Glechoma hederacea*) and canopies were becoming more closed (= increase in alder seed abundance); woody species *Acer campestre* and *Cornus sanguinea* started to appear. Relatively the largest number of *Betula pendula* seeds (2 peaks in MZ-2) indicates that mature birch trees must have been present back then in this part of Horský park PA, possibly due to disturbances in the previous period (= spreading of pioneer tree species on open grounds). Interestingly, birch is currently not reported from Horský park at all, cf. Reháčková 2009). Among wet tolerant species there were still present in this zone *Scirpus sylvaticus*, *Carex otrubae* / *vulpina*, even *Cyperus fuscus* (in 20 – 25 cm), but also *Lythrum salicaria*. The studied site still remained markedly ruderalised (= *Stellaria* cf. *ruderalis*, *Urtica dioica*). Along with neophytic *Xanthoxalis dillenii* / *stricta* (= weed in gardens / parks) solely in this zone occurred seeds of *Chenopodium* sp. Out of non indigenous *Xanthoxalis* species, already Lumnitzer reported *Oxalis corniculata* to be found at a single site in Bratislava (... *ad fossam hinter dem Kindsgraben*; 1791, p. 184). In the 1820s *O. stricta* was abundant in shrub undergrowth and along fences in several locations, including Thomas's Spring and Patzenhäusel (*In dumetis et maceriis in Kindsgraben, pone Thomasbrunn, ad Patzenhäusel alibique copiose*; Endlicher 1830, p. 428).

Zone MZ-3 (0 – 20 cm; cca. 1990 – present). Essentially, seed findings are indicative of current situation—closed, shaded forest stand dominated by *Alnus glutinosa*, but also with other species in a dense understorey / shrub layer *in situ* or in close vicinity. Curve of *Sambucus nigra* is almost continuous; *Prunus padus* and indigenous *Pyracantha coccinea* were also present. Exclusively in this zone, the seeds of nanophanerophyte shrub *Rubus* sp. and of wild garlic *Allium ursinum* (woodland species) were present. The presence of wet tolerant plants has declined and has only been captured in lower part of the zone (below 15 cm). Nor ruderal *Xanthoxalis*, *Chenopodiaceae*, neither *Stellaria ruderalis* / *neglecta* have been present. However, nitrophilous *Urtica dioica* reached its maximum abundance here. It is worth to note that seeds of *Vitis vinifera* were also found in samples from 14 – 19 cm.

As to a faunistic record, besides cocoons of Annelids and fragments of insects, also few shells of Mollusca were retrieved. These were only present in topsoil 0 – 7 cm (due to slightly acidic soil reaction – Fig. 8) and represented by *Alinda biplicata*, *Discus rotundatus* and shell fragments of Clausillidae. *Discus rotundatus* is a forest mesohygrophilous species, typical for secondary riparian communities; it also tolerates disturbed or altered habitats. *Alinda biplicata* is an euryecious forest species, also commonplace in secondary habitats – parks, gardens, shrublands etc. Both species have already been recorded at this site in 2017 (Čejka et al. 2020).

#### Current vegetation

Cover-abundance values and layer abundancies are listed in Table 4.

*Relevée no. 1*: even-aged alder wood with the coring site MF-1 in the lowermost part of HP with native woody plants in undergrowth and ground layer, mainly common ash, and a field maple (of different age and heights). Neophytic *Impatiens parviflora* dominates a field layer – indicating synanthropization. Plot area 25×30 m.



Fig. 10. Forest swamp in the lower part of Horský park PA crossed by a boardwalk (view from the east)

*Relevée no. 2:* planted *Metasequoia glyptostroboides* stand on the base of the slope, but still on the waterlogged swampy ground (Fig. 11). Plot area 30×30 m, coordinates 48° 08' 9.6" N, 17° 04' 52.6" E. *Hedera helix* dominates a field layer and also twines around trunks of canopy trees. Abundant woody juveniles. A single specimen of *Taxus baccata* (2 m tall) was present in a shrub layer, along with *Sambucus nigra*.

*Relevée no. 3:* Mixed woodland with rich shrub layer, located somewhat higher along the catena, already at the foot slope. The soil in this area is slightly moist, already well drained, and not being waterlogged. Plot area 25×20 m. Herb layer was heavily shaded by trees and shrubs. Woody juveniles were abundant, mainly *Acer platanoides*.

Tab. 4. Phytosociological table, relevée 1 – 3

| Phytosociological relevée n.        | 1  | 2  | 3  | Phytosociological relevée n.  | 1   | 2   | 3   |
|-------------------------------------|----|----|----|-------------------------------|-----|-----|-----|
| E3                                  |    |    |    | E1 Cover area (%)             | 60  | 40  | 60  |
| E3-1 Cover area (%)                 | 65 | 75 | 75 | <i>Swida alba</i>             | r   | -   | -   |
| <i>Alnus glutinosa</i>              | -  | r  | -  | <i>Impatiens parviflora</i>   | 4.3 | 2.3 | +   |
| <i>Metasequoia glyptostroboides</i> | -  | 4  | +  | <i>Circaea lutetiana</i>      | 2.1 | 2.1 | +   |
| <i>Acer platanoides</i>             | -  | -  | 3  | <i>Geum urbanum</i>           | 2.2 | 1.1 | +   |
| <i>Salix cf. alba</i>               | 1  | -  | -  | <i>Hedera helix</i>           | r   | 3.4 | 3.3 |
| <i>Fraxinus excelsior</i>           | -  | -  | 2  | <i>Acer platanoides</i>       | r   | 2.1 | 3.1 |
| <i>Tilia platyphyllos</i>           | -  | -  | 1  | <i>Fraxinus excelsior</i>     | 2.1 | +   | +   |
| E3-2 Cover area (%)                 | 15 | 20 | 25 | <i>Acer campestre</i>         | +   | 1.1 |     |
| <i>Hedera helix</i>                 | r  | 2  | +  | <i>Euonymus europaea</i>      | r   | r   | +   |
| <i>Fraxinus excelsior</i>           | 2  | +  | -  | <i>Urtica dioica</i>          | 1.2 |     |     |
| <i>Carpinus betulus</i>             | -  | +  | 1  | <i>Carex remota</i>           | 1.2 |     |     |
| <i>Acer platanoides</i>             | -  | 1  | 2  | <i>Prunus padus</i>           |     | 1.1 | +   |
| <i>Salix alba</i>                   | 1  | -  | -  | <i>Rubus caesius</i>          | r   |     | r   |
| <i>Alnus glutinosa</i>              | +  | -  | -  | <i>Aesculus hippocastanum</i> | r   | r   |     |
| <i>Juglans nigra</i>                | +  | -  | -  | <i>Geranium robertianum</i>   | r   | r   |     |
| <i>Ulmus laevis</i>                 | +  | -  | -  | <i>Festuca gigantea</i>       | r   | r   |     |

continuation of the tab. 4

|                                     |    |    |    |                              |   |   |   |
|-------------------------------------|----|----|----|------------------------------|---|---|---|
| <i>Prunus padus</i>                 | -  | 1  | -  | <i>Acer pseudoplatanus</i>   |   | r | 1 |
| <i>Tilia platyphyllos</i>           | -  | +  | -  | <i>Tilia platyphyllos</i>    |   | r | + |
| <i>Tilia cordata</i>                | -  | -  | 1  | <i>Juglans nigra</i>         |   | + | + |
| <i>Metasequoia glyptostroboides</i> | -  | +  | -  | <i>Carpinus betulus</i>      |   | + | + |
| <i>Acer campestre</i>               | -  | -  | 1  | <i>Equisetum palustre</i>    | + |   |   |
| E2 Cover area (%)                   | 30 | 55 | 60 | <i>Phalaris arundinacea</i>  | r |   |   |
| <i>Acer campestre</i>               | 2  | 1  | 2  | <i>Rosa canina</i>           | r |   |   |
| <i>Fraxinus excelsior</i>           | 2  | 1  |    | <i>Phragmites australis</i>  | + |   |   |
| <i>Acer platanoides</i>             | +  | 1  | 3  | <i>Calystegia sepium</i>     | r |   |   |
| <i>Prunus padus</i>                 | 1  | 1  | 1  | <i>Carex acuta</i>           | + |   |   |
| <i>Acer pseudoplatanus</i>          |    |    | +  | <i>Athyrium filix-femina</i> |   | r |   |
| <i>Euonymus europaea</i>            | +  | +  | +  | <i>Rubus fruticosus</i> agg. |   | r |   |
| <i>Sambucus nigra</i>               |    | 2  | r  | <i>Corylus avellana</i>      |   | r |   |
| <i>Tilia platyphyllos</i>           |    | 1  | +  | <i>Crataegus monogyna</i>    |   | r |   |
| <i>Prunus avium</i>                 | +  |    |    | <i>Cornus sanguinea</i>      |   |   | r |
| <i>Juglans nigra</i>                | +  |    |    | <i>Ligustrum vulgare</i>     |   | r |   |
| <i>Carpinus betulus</i>             |    |    | +  | <i>Tilia cordata</i>         |   | + |   |
| <i>Crataegus monogyna</i>           |    | r  |    | <i>Fragaria vesca</i>        |   | r |   |
| <i>Tilia cordata</i>                |    |    | +  | <i>Ribes</i> sp.             |   |   | r |
| <i>Taxus baccata</i>                |    | r  |    |                              |   |   |   |

Explanations: E3 – tree layer, E3-1 – main canopy, E3-2 – lower canopy, E2 – shrub layer, E1 – field layer, 2.3 – combined values of abundance and dominance, r – rare species, + – plant individuals with cover area < 1 %.

Present-day forest vegetation (relevées 1, 2) documents the presence of map unit ash-alder submontane floodplain forest of the suballiance *Alnenion glutinoso-incanae* (map code: Ls1.3). This is evidenced by a species *Alnus glutinosa*, *Acer pseudoplatanus*, *Fraxinus excelsior*, *Carex remota*, *Circaea lutetiana*, *Rubus caesius*, *Rubus fruticosus* agg. or *Urtica dioica* (Stanová and Valachovič 2002 and Jarolímek and Šibík 2008).

## DISCUSSION

The list of species from the location “*unter dem Pazenhäusel*” (Lumnitzer 1791) in the 1780s suggests that most probably back then, communities of the class *Scheuchzerio-Caricetea fuscae* R. Tx. 1937, alliance *Caricion fuscae* Koch 1926 em. Br.-Bl. 1949 existed at this place. They populate more or less permanently waterlogged sites, where accumulated organic matter is undergoing processes of peat formation. Three major ecological gradients determine their floristic composition: nutrient status of soil water, content of organic particles in deposits and water level in the habitat, respectively (Hájek and Háberová 2001). Communities of *Caricion fuscae* are native low-grown sedge communities of peaty to fen-meadows on shallow histosols or waterlogged soils. They occur mainly on nutrient-poor substrates derived from sands or granites, but at higher altitudes also on richer substrates (e. g. andesites). The communities mainly occur in colline to montane belt of Central Europe, where they have developed through human action.

Most likely, the examined wetland habitat was represented by a plant association of *Caricetum goodenowii* J. Braun 1915, which is a two-storey sedge community with less developed moss layer and higher presence of dicotyledon plants and

rushes. It prefers slope or valley locations with permanently high groundwater level, in an initial stage of peat formation. The environment is mesotrophic to neutral with slightly acidic soil reaction. Community is young and represents a replacement vegetation after the forest stands of wet tolerant trees. It is dependent on human intervention – requires mowing, pasture and/or tree species removal. The association is abundant in Slovakia and elsewhere in Central Europe. However, a number of still existing sites have been adversely affected by water regime alteration and land use changes. This result in decline of moss layer, reduction of biodiversity in E1 of all peatland and marsh species and to accelerated succession (Hájek and Háberová 2001).

Still in the 20th century, similar habitats were to be found scattered across the territory of Greater Bratislava, e. g. in the phytogeographical region of Devínska Kobyla Mt. (Valenta in litt., Letz 2000). For example, meadows with *Pedicularis palustris*, *Lathyrus pannonicus*, *Orchis coriophora* still existed in 1949 by Lamač (Valenta 1949 in Ptačovský 1959). Additional peaty meadow was located alongside the Pekná cesta road. In 1920s and 1930s *P. palustris*, *Gentiana pneumonanthe*, *Orchis palustris*, *L. pannonicus*, *Oenanthe silaifolia*, *Salix rosmarinifolia* and *Iris sibirica* were commonplace there. However, a site disappeared after WW II when the whole area has been drained (Ptačovský 1959).



Fig. 11. View of the association *Caricetum goodenowii*. Mown fen-meadows with *Ériophorum angustifolium*, *Scirpus sylvaticus*, *Filipendula ulmaria*, *Lysimachia vulgaris* and *Dactylorhiza majalis*

Veporské vrchy Mts., Šoltýska, Slovakia. Courtesy: R. Hrivnák.

Also, at the eastern part of the Lamač Gate, favourable conditions for a wetland habitat originated after the last glaciation. An interplay of tectonics, geological conditions, hydrologic and geomorphic processes gave rise to a waterlogged terrain on the valley floor. Small streams gravitating into the lowermost parts of slightly inclined depressed block and retarded groundwater flow led to perched water table, waterlogging and formation of hydric and semi-hydric soils alongside local brook-let and at the foot slopes. Prior to human agency, the area southward from the present-day Brnianska street was covered by Carpathian oak-hornbeam woods (*Carici pilosae-Carpinenion betuli*), even with *Quercus cerris* oak woods (*Quercetum petraeae-cerris* s. l. – Michalko et al. 1987). In the lowermost elevations, riparian alluvial alder woods with *Alnus glutinosa* of the alliance *Alnenion glutinoso-incanae* Oberd (1953) existed there.

At the latest in the Middle Ages, alder woods alongside the local brook were cleared and replaced by **secondary wet and waterlogged fen-meadows**, with a plant community of *Caricetum goodenowii* J. Braun 1915 with several species that are today listed as rare and endangered in Slovakia.

Due to the terrain configuration, the wetland habitat has a markedly elongated platform shape, almost 600 m long, but probably not much wider than 100 m (Fig. 12). Towards NE these fens merged into more mesophilous grasslands. Upon the establishment of the local farmstead (Eleonóra majer), they could have been occasionally grazed. In general, the use of local grasslands was also weather-dependent: in cool wet seasons they were only mowed to produce hay, in drought spells they may have been even ploughed mainly in the transition zone. Perhaps the 1870 map just captured such situation.

Accumulation of organic matter in wet conditions could have been also favoured by a slope aspect and local microclimate—somewhat shaded position at the base of the depressed valley and foot slopes of Machnáč, with draining of cold air during calm nights. Also, hydroclimatic fluctuations during Little Ice Age (LIA) may have played a role: severe winters were frequent, along with wet summers (cf. Melo et al. 2016). This could have led to a higher discharge of rivulets feeding a depression, particularly during the 17 – 19th century.

Even three decades after Lumnitzer's *Flora Posoniensis*, the local wetland was thriving. According to Endlicher (1830), a number of original marsh species still occurred *infra Patzenhäusel* on local „marshy meadows“ and/or „somewhat moist meadows“ (*in pratis paludosis*, ... *humidiusculis*), e. g. *Pedicularis palustris* (p. 256), *Peucedanum palustre* (p. 347), *Epilobium palustre* (p. 368), *Gratiola officinalis* (p. 251), *Scorzonera humilis* (p. 286), *Scirpus sylvaticus* (p. 132), *Laserpitium prutenicum* (p. 1209) or *Molinia* sp. (p. 121). *Eriophorum angustifolium* (p. 133) and *Filipendula ulmaria* (469) were even abundant there (*copiose*).

As to studied profile, both paleoecological analysis and radiocarbon dating indicate that mainly the topsoil part of the examined profile is relatively young. Evolution of the site was affected by soil flushes either from transport communication along the valley bottom (the current Lovinský's road), or directly in situ from a local footpath which is one of the main entrances to Horský park. Few decades ago, a footpath seemed to be more frequented and wider (Fig. 7). The relatively young age of the sediments is also evidenced by several anthropic artifacts present all along—fragments of coal cinder (particularly abundant in 35 – 55 cm), brick or glass (in 35 – 42 cm and 50 – 55 cm). Factors controlling development of the site were:



1. rainfall events resulting in increased discharge of local rivulet and/or slopewash, influx of mineral particles and potentially also erosion, 2. direct and indirect anthropogenic interference-planting and management of woody vegetation, construction activities in surroundings, technical adjustments to the wetland itself etc.

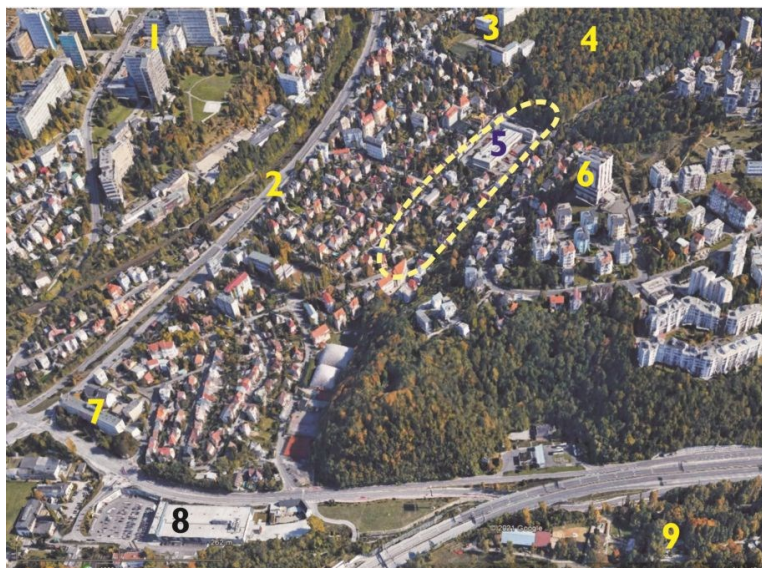


Fig. 12. Position of a historical wet meadow habitat in the current urban area, Bratislava – West (source: Google Earth). Oblique aerial view from the west.

Landmarks: 1 – Kramáre hospital area, 2 – Brnianska street, 3 – student's house, 4 – urban forest Horský park, 5 – trolleybus shed and garage, 6 – Slovak National Archives, 7 – State Geological Institute of D. Štúr, 8 – Kaufland hypermarket, 9 – ZOO Bratislava.

Possible **sedimentation hiatus**, most probably related to erosion events during the LIA period (sometime post 1685 AD), is indicated by interface of zones MZ-2 and MZ-3 and by radiocarbon ages. Soil erosion could have been linked either with clearings / cuts of forest and/or with terrain adjustments – establishment of a land park in 1870. On the other side, local disturbances could have also been related to the planting of *Metasequoia* sometime in the 1950s – 1970s. Current trees are estimated to be some 50 – 60 years old (Program starostlivosti ... 2019), which is in good accord with radiocarbon-dated seeds of *Alnus glutinosa* (samples HP-2013-2 – 4).

Soil moisture at this particular site likely oscillated more in the past and due to the location of the site at the upper margin of former wetland, it was not only affected by slopewash, but also by erosional events. Water regime at the site was definitely influenced by construction of large premises (trolleybus depot) at the Hroboňova ul. street in 1960s. Levelling of the terrain through anthropogenic deposits (up to 8 m thick) in the line of valley floor produced an obstacle for the groundwater flow. This even resulted in static deformations of the premises (Vlasková and Pisoň 1991). Petty technical adjustments in two recent decades also contributed to a more favourable status of the local wetland in HP. In the material which outlines scheduled management plan for this park for the period 2019 –



2048 a local wetland has been delimited as a „wetland in the layover zone“. An artificial pond should be excavated nearby in order to make better conditions for amphibians and prolong the life of the wetland itself (Program starostlivosti ... 2019).

Wet forest of HP undoubtedly represents—both from spatial and genetic viewpoint – **the last surviving remnant of examined wetland habitat** documented by Lumnitzer in 18th century (1791). Already Letz has anticipated that more thorough and long-term observations could even “on this quite overgrown site” confirm some of Lumnitzer’s interesting data. In 1998 he recorded in this location the species *Carex gracilis*, *C. acutiformis*, *C. vulpina*, *C. remota* and *Scirpus sylvaticus*, being fairly scarce, particularly in the central part of the city (Letz 2000).

Of original Lumnitzer’s species, we managed to confirm in this research, *Scirpus sylvaticus* and *Lythrum salicaria* by palaeoecological record. In addition, also black alder is possibly evidenced here as early as the 17th century (14C-dated seed). Besides them, a macrofossil record has also documented several other plants of the local vegetation. Except of different sedges (*Carex remota*, *Carex* cf. *acutiformis*, *C. otrubae* / *vulpina*, *Cyperus fuscus*), also additional plants were typical of earlier developmental stages, indicative of both wet and ruderalised places – *Isolepis setacea*, *Stellaria* cf. *ruderalis* and grass *Glyceria* cf. *declinata*. Whether some of them may have been reported from this site by the 19th and 20th century botanists remains yet to be verified.

The wood clubrush (*Scirpus sylvaticus*) must have been an important component of the local vegetation. By repeated visit on the site (12th August 2021) we observed its expansion, since there are currently two groups of *S. sylvaticus* with the total area of 39 m<sup>2</sup> (relevée N. 2), also with a few specimens of *Filipendula ulmaria*. These plants must have regenerated from the seed bank after the site has been recently positively affected by artificial rewetting. *S. sylvaticus* (along with *Equisetum* sp. and *Lythrum salicaria*) also grows alongside a small rivulet in the depressed area of Průger-Wallner garden, which was recently open to public (in 2021) and is only 760 m away from our studied site as the crow flies (Fig. 4).

Data presented here are also important for studying of how non-indigenous species spread in the landscape. This applies not only to species evidenced by palaeo-record (*Pyracantha coccinea*, *Xanthoxalis dillenii* / *stricta*), but also to current vegetation. List of allochthonous species, which have already been long present in HP (Reháčková 2009) and have also been evidenced by our survey (Tab. 5), was also updated by a new species – *Swida alba*. It was found to grow in the shrub layer of relevée no. 1. Native to northern Asia, it is being widely planted as ornamental shrub. It has not been reported in the checklist by Reháčková (2009).

## CONCLUSION

In this paper we present the findings and the analysis of a defunct wetland habitat in the central part of Bratislava, which has been firstly evidenced by historical accounts of Lumnitzer (1791). We have reconstructed the character, position, and the initial area of this wetland, but also the controlling factors which had determined its existence.

Fen habitat supporting some scarce, protected, or endangered marsh species, currently rare at the territory of Bratislava, was located in what is now central part of the city. Its decline was linked to landscape changes over the last two centuries.

The wetland habitat “rediscovered” by Letz (2000) was located in “submontane” parts of urban area, in the lowermost elevations of the intermontane depressed area. In the 18th century, this place was farther away from the town and had a rural character with vineyards, ploughland, grassland and remnant woods. By that time occupants of Bratislava began to make first recreational and sightseeing trips into the surrounding country. Today, the place has been changed beyond recognition by urban development. By coincidence, a number of institutions and well-known landmarks of national importance exist today in its close surroundings (Fig. 12).

Interplay of tectonics, geology and geomorphic processes in the Quaternary and Anthropocene have formed the topographic relief of the studied area. Retarded runoff and accumulation of groundwaters at its lowest elevations, coupled with finer co-alluvial deposits and perched water table resulted in permanent waterlogging and paludification. Through human action, a riparian alderwoods growing alongside the local brooklet were replaced by secondary wet and waterlogged fen-meadows habitat most probably with a plant community of *Caricetum goodenowii* J. Braun 1915. With the area of some 5 hectares, it represented an important local *biocenter*, supporting a number of wetland plants and animals (e.g. breeding grounds for Amphibians) amidst a cultivated country.

From the mid-19th century, human activities began to increase, especially the development of transport infrastructure (long-distance and local roads, railway in 1848) and residential construction, which began as isolated houses and outbuildings. Even climate fluctuations may have contributed to the desiccation and ploughing of grasslands, particularly very dry and warm decade of 1860s (cf. Kiss 2009). In 1890s, regulation of local brook triggered a degradation of plant community. Progressive urban development of this area has been documented by historical maps and plans. Eventually, as late as after 1950, last narrow alluvial strip along Lovinského street was transformed into individual houses and public premises.

In this study, we have confirmed by both field research and palaeoecological evidence that a current forest swamp at Horský park represents, genetically, the last *remnant of the historical wetland*, yet it already lies at the margin of the original boggy habitat. Plant macrofossils, anthropic artefacts and radiocarbon data explain co-alluvial character of the deposits, comparatively young age of upper fill and heavy anthropogenic interference. Despite this, our data contributes to the knowledge of former vegetation and initial conditions of the area.

Further to the results of this study, we suggest there still exist favourable conditions for a potentially successful palaeoecological study in this area, able to capture and validate organic deposits of the initial wetlands. Despite draining of the area, local groundwater level is fairly shallow. Water table is still perched either by layers with low permeability or restricted by the foundations of numerous building structures, creating obstacles for groundwater flow (cf. Vlasková and Pisoň 1991). This allows us to suggest, that the original organic layers may have not undergone mineralisation entirely and macrofossils may still be preserved in reducing conditions to provide further evidence of original wetland vegetation.

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## ZANIKNUTÝ BIOTOP SLATINNÝCH LÚK – VÝZNAMNÉ HISTORICKÉ BIOCENTRUM V SRDCI BRATISLAVY, SLOVENSKO

V príspevku predstavujeme inovatívny prístup k rekonštrukcii zaniknutých mokradných biotopov a historického využívania krajiny, primárne založený na využití botanických dát. Prezentovaný interdisciplinárny výskum vychádza nielen z analýzy jestvujúcich geologických, geomorfologických, kartografických a botanických údajov, ale opiera sa aj o vlastný terénny výskum vegetácie a paleoekologickú analýzu sedimentov historickej mokrade, doplnenú rádiokarbónovým datovaním.

V 18. storočí vydal Štefan Lumnitzer prvé moderné systematické dielo o rastlinách Bratislavy a jej okolia (*Flora Posoniensis* ... 1791). Celkove v ňom zachytil 1 294 rastlinných druhov, pričom pri mnohých udáva aj miesta ich výskytu – vyše 100 rôznych historických lokalít. Vďaka tomu je v niektorých prípadoch možné dokonca rekonštruovať aj výskyt a podobu určitých zaniknutých biotopov. Takou je aj historická lokalita „unter dem Pazenhäusel“ („pod Púčkovým domom“). Na základe poznania ekologických nárokov celkove 20 druhov rastlín, ktoré odtiaľ Lumnitzer uviedol, je zrejme, že sa tam rozprestieral zaujímavý biotop slatinných až zrašelinených lúk s výskytom viacerých dnes vzácnych, ohrozených a zriedkavých močiarnych druhov rastlín (Letz 2000).

V príspevku rekonštruujeme nielen lokalizáciu uvedenej mokrade, ale aj prírodné podmienky, ktoré determinovali jej vznik. Tiahla sa od SZ okraja dnešného Horského parku približne po dnešnú ulicu Pri Habánskom mlyne. Mokrad s rozlohou asi 5 ha bola pretiahnutého tvaru, dlhá do 600 m, no so šírkou zrejme len do 100 m. Lúčne spoločenstvo bolo pravdepodobne reprezentované asociáciou *Caricetum goodenowii*. Išlo o človekom podmienené (pravidelné kosenie) sekundárne spoločenstvo po pôvodnom podmáčanom lese (prípotočná jelšina), vyrúbanom ešte v stredoveku. Močaristé lúky sa pôvodne nachádzali na periférii mesta v historickom záhone *Hamischgrund*, v krajine, ktorá mala vidiecky charakter (vinice, lúky a izolované lesy). V druhej polovici 18. storočia sa širšie okolie práve začínalo stávať cieľom rekreačných a poznávacích výletov mešťanov. Mokrad vznikla na dne poklesnutého bloku so zníženým sklonom a spomaleným odtokom vody vo východnej časti Lamačskej brány, kde tak reliéfne, ako aj hydrologické a geologické pomery (polohy hlin a ílovitých pieskov pôsobiace ako akvitard) determinovali trvalé celoročné podmáčanie terénu pozdĺž horského potoka a úpäti priľahlých svahov. Istú úlohu zohrávalo aj čiastočné zatienenie lokality a mikroklimatické pomery.

Degradácia historického biotopu, ktorý bol dôležitým biocentrom mokradných druhov v poľnohospodárskej krajine, sa začala koncom 19. storočia (historické mapy). Zhruba do roku 1960 napokon celú oblasť pohltilo rozvíjajúce sa mesto. Na mieste zaniknutej lokality sa dnes rozprestiera uličná zástavba. V blízkosti sa nachádza viacero celoslovensky významných inštitúcií (Slovenský národný archív, Geologický ústav D. Štúra, ZOO Bratislava a pod.). Napriek kanalizácii miestneho potoka sa fragment mokrade podnes zachoval na okraji Horského parku. Jej sedimentárnu výplň sme analyzovali v prieskumnom vrte. Profil, hlboký 80 cm, obsahoval množstvo antropických artefaktov (kúsky uhlia, fragmenty tehál a skla), ale aj rastlinných a živočíšnych makrozvyškov. Študované sedimenty sú prevažne minerálne a majú koluviálno-fluviálny charakter. Vývoj stanovišta ovplyvňovali periodické splachy, ale aj erózia pôdy (hyát v sedimentárnom zázname). Analýza sedimentov poukázala na relatívne mladý vek najmä vrchnej časti výplne, hoci najstaršie sedimenty môžu siahať až do 17. storočia (rádiouhlíkom datované semienka jelše, *Alnus glutinosa*). Rozbor celkove 727 semien patriacich najmenej 44 rastlinným druhom priniesol originálne poznatky o charaktere stanovišta v troch rozdielnych makrozvyškových zónach (MZ 1 – 3), sukcesii vegetácie mokrade a jej blízkeho okolia. Zistili sa nielen druhy udávané už Lumnitzerom (napr. *Scirpus sylvaticus* a *Lythrum salicaria*), ale aj ďalšie rastliny, ktoré boli typické pre staršie vývojové štádiá mokrade (*Isolepis setacea*, *Glyceria* cf. *declinata*). Lokalita bola

pôvodne omnoho viac otvorená – okraj podmáčanej lúky – a len postupne došlo k zapojeniu porastu drevín a rozvoju lesného prostredia. Celkove skladba druhov poukazuje na výrazné antropické ovplyvnenie súvisiace so zásahmi človeka v 19. a 20. storočí (založenie parku v roku 1870, výsadba porastu *Metasequoia glyptostroboides* medzi rokmi 1950 – 1980).

Zistenie, že súčasný fragment lesnej mokrade je priamym genetickým zvyškom a kontinantom pôvodnej historickej mokrade, hoci situovaný už na jej JV okraji, má zásadný význam nielen pre poznanie pôvodnej biodiverzity územia hlavného mesta Slovenska a histórie chráneného areálu Horský park, ale aj pre ďalší manažment tohto územia.



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