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Floodplain vegetation of the restored Jedlový Potok stream in the Bohemian Forest

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Abstract
A segment of the Jedlový Potok stream, a tributary of the Teplá Vltava River, was restored in 2015 as part of a large restoration programme aiming to ameliorate the water regime in the Vltavský Luh wetland complex. This paper describes plant communities occurring in the Jedlový Potok floodplain at the time of its restoration and immediately afterwards with the aim to provide baseline information for further monitoring of vegetation development. Four main types of open wetland habitats were distinguished. An extensively mown wet *Cirsium* meadow and a *Phalaris arundinacea* marsh occurred in the riparian zone with a more fluctuating water table while a short-sedge fen and an *Eriophorum vaginatum* mire formed a peatland zone further away from the watercourse. In spite of some degradation caused by previous drainage, the communities have preserved their characteristic physiognomy and species composition and thus represent good examples of wetland plant communities of the Vltavský Luh wetland complex.

Key words: biodiversity, Bohemian Forest, stream restoration, water regime, wetlands, zonation

Introduction

Numerous watercourses were channelized in the Bohemian Forest (Šumava in Czech) in the past in order to increase the production of the surrounding agricultural land and woodland. These measures have seriously altered the water regime of adjacent wetlands, which in turn changed soil conditions and microclimate and, consequently, also the biota inhabiting these habitats.

Within a large restoration programme of the Bohemian Forest wetlands, near-natural conditions were restored among others in three streams, the Hučina, the Jedlový Potok, and the Žlebský Potok, which feed the wetland complex of Vltavský Luh. Wetland vegetation, physico-chemical parameters of the stream water, communities of benthic invertebrates, and aquatic and wetland vegetation have been monitored on these sites since the restoration (Bojková et al. 2015).

The Jedlový Potok stream is a left-hand tributary of the Teplá Vltava stream, to which it discharges near the village Dobrá. The middle course of the Jedlový Potok stream was moved to a new bed in connection with the railway construction at the end of the 19th century. In the 1950s, the stream bed was straightened along most of its course and reinforced with concrete blocks and stones. The artificial bed was 0.5–1.1 m deep and, at some places, up to 5 m wide. The canal drained adjacent meadows and also served as part of the drainage system along the perimeter of the nearby Soumarský Most peatland, from which peat was excavated.

In autumn 2015, the downstream, straightened segment of the Jedlový Potok stream was restored. The restoration included the construction of a new meandering bed, which was 0.2-0.4 m deep and, except for through-flow pools, less than 2 m wide. The former artificial channel was filled up by soil except for several parts which were modified into pools. The 985-m long, formerly channelized section of the Jedlový Potok stream was thus extended to the restored length of 1115 m.

The restoration has initiated the natural development of the stream bed and its floodplain; it is anticipated that the changes in water regime, namely the increased groundwater level, will affect also the local vegetation. This paper describes the plant communities in the Jedlový Potok floodplain at the time of its restoration and immediately afterwards with the aim to provide a baseline information for potential long-term monitoring of the restoration effects.

Methods

Eight permanent plots (15–25 m^2, see Table 1) were laid in the floodplain of the restored segment of the Jedlový Potok stream. Two quadrats were placed in each of four habitat types, distinguished by their physiognomy, dominant plant species and distance from the stream bed (Fig. 1).

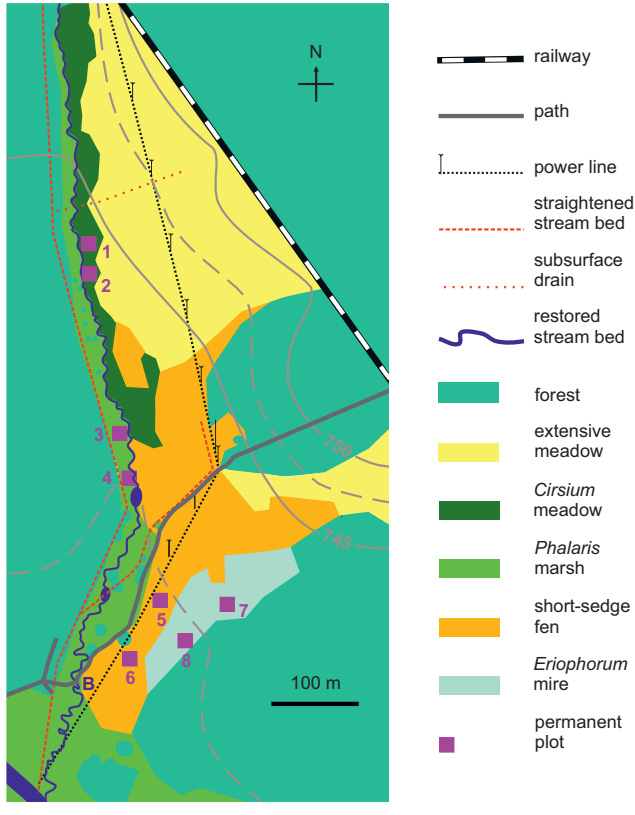

Fig. 1. A schematic map of the restored part of the Jedlový Potok stream and its surroundings. B – bridge.

(i) A wet meadow habitat with a high dominance of dicotyledonous species (called wet *Cirsium* meadow in further text), which formed a several meter wide interface between the stream and an extensively managed meadow. The habitat lies on a gley soil based on quaternary deluvial sediments (ČGS 2018a,b). The soil is mineral, sandy loam by texture.

(ii) A marsh habitat overgrown with *Phalaris arundinacea* (*Phalaris* marsh), which extended along the stream in the unmanaged part of the open floodplain. This habitat also lies on poorly developed soil on sandy sediments.

(iii) A waterlogged peaty habitat with a high dominance of sedges and rushes, situated within 100 m from the stream (short-sedge fen). The soil is gley based on quaternary deluvial sediments. In contrast to the habitats above, it has a surface organic horizon more than 0.3 m deep (ČGS 2018a,b).

(iv) A mire habitat with *Eriophorum vaginatum* and *Molinia caerulea* (*Eriophorum* mire), situated more than 100 m away from the stream and close to the waterlogged spruce forest neighbouring the open floodplain. The soil is histosol based on a thick layer of peat (ČGS 2018a,b).

The plots were marked on 21 August 2015 except for the two plots with *P. arundinacea*, which were selected on 29 June 2017 (this particular part of the floodplain was not accessible in summer 2015 because of the construction works). A perforated PVC tube (0.05 m in diameter) was installed to a depth of 0.5–0.6 m near each plot for measurement of the depth to the groundwater level. The groundwater levels were measured approximately at one-month intervals from June to October 2017 and from April to July 2018.

Lists of phanerogam species were made within each habitat type in August 2015, i.e. at the time the restoration started. Phytosociological relevés of the permanent plots were recorded on three dates of 2017 (1–2 June, 28–29 June and 27–28 July) in order to cover the late spring, early summer and late summer aspects of the vegetation, and repeated in early summer 2018 (12 June). The cover of phanerogam species was recorded using a combined abundance-dominance scale, in which the symbol "r" was used for one or several small individuals and the symbol "+" for one big or many small individuals with a cover smaller than 1%. A species dominance ≥1% was estimated as percentage of total cover.

With some exceptions, the same plant species were found in the habitats in 2015, 2017 and 2018. Also differences in species cover among the dates of 2017 were fairly small and largely corresponded with the species' phenological phases. Therefore, only relevés taken on early summer dates of the two consecutive years (29 June 2017 and 12 June 2018) are presented here.

The names of phanerogams follow Kubát et al. (2002). Bryophytes were classified only to broad taxonomic categories. The habitat classification follows Chytrý et al. (2010). The diagnostic species of syntaxonomical units are based on Chytrý (2007, 2011).

Results and discussion

Groundwater level

The habitats differed in their water regimes. Both habitats occurring close to the watercourse had great ranges of water level fluctuations. The wet *Cirsium* meadow had the lowest minima and medians of the groundwater depth, followed by the *Phalaris* marsh (Fig. 2). On the *Cirsium* meadow, even the maximum groundwater levels remained below the soil surface at all measurement dates; this was the case also at a peak discharge following continuous rain on 13 June 2018, when flood warnings (i.e. the 2nd level of flood activity) were issued by the nearest measurement stations at the Teplá Vltava stream in Lenora and Chlum. In comparison, the habitats occurring at greater distances from the watercourse, i.e. the short sedge fen

and the *Eriophorum* mire had a more stable water regime with smaller fluctuations. The mean groundwater level remained within a 0.2-m depth from the soil surface and the habitats were shallowly flooded at times of continuous rain.

Although the ranges of groundwater level fluctuations correspond to the general knowledge of the habitats, the exact values should be interpreted with caution because the number of sampling was fairly small, the sampling dates did not reflect the frequency and duration of wet and dry periods and they did not include early spring. In addition, it should be born in mind that they describe the state after (not before) the restoration.

Characteristics of the plant communities

The wet *Cirsium* meadow had by far the greatest species richness with a total of 47 phanerogams (Table 1). Dicots constituted more than 50% of the species number and 50% total cover (Table 2). The community included diagnostic species of the association *Holcetum lanati* 1934, characterized by soils that are moist in spring but can dry out in the second part of the vegetation season, when the groundwater level can drop to as much as –1 m. Such conditions were probably common before the stream restoration. The rich representation of dicots both in species number and cover together with the respective diagnostic species are features of the association *Polygono bistortae-Cirsietum heterophylli* Balátová-Tuláčková 1975, which typically occur along watercourses on soils that are moist throughout the vegetation season. This habitat corresponded to the *Deschampsia caespitosa-Alopecurus pratensis* community according to Bufková et al. (2005).

The *Phalaris* marsh hosted a species-poor community with one or two strong dominants (*P. arundinacea* in plot 3 and its mixture with *Scirpus sylvaticus* in the wetter plot 4). It corresponded to the association *Phalaridetum arundinaceae* Libbert 1931, which is supported

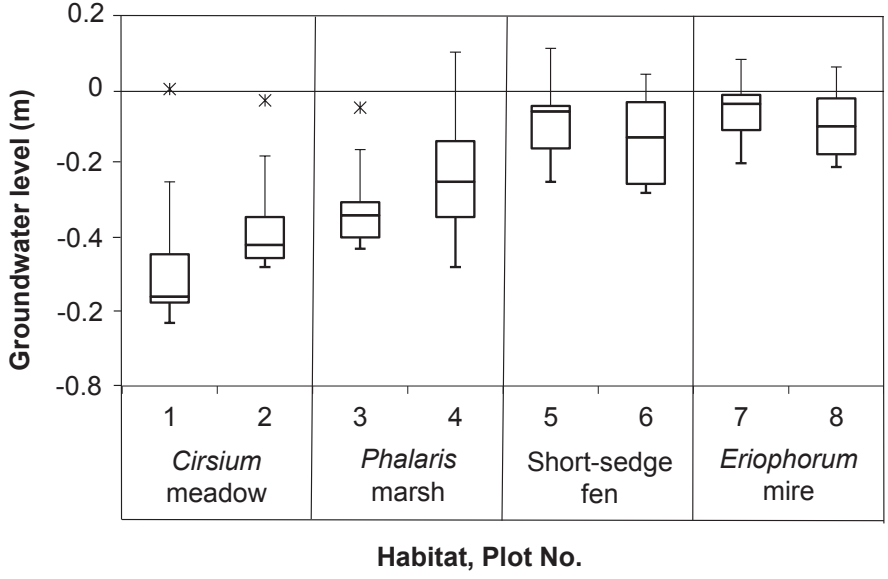

Fig. 2. Ranges of groundwater level fluctuations recorded on permanent plots in the restored part of the Jedlový Potok floodplain in 2017–2018. The graph shows medians (squares), 25 and 75 percentiles (boxes), minima and maxima (bars) of 10 sampling dates; the outliers (asterisks) in plots 1–3 and maxima in other plots were measured during an extremely high discharge on 13 June 2018.

Table 1. Representation of phanerogam species in the phytosociological relevés recorded on permanent plots in the floodplain of Jedlový Potok. Numbers indicate percentage of species cover (in %); r: species present as one or few small individuals; +: species present as one robust or a greater number of small individuals with negligible cover. Even relevés (No. 1, 3, 5, 7, 9, 11, 13, 15) were taken on 28–29 June 2017; odd relevés (No. 2, 4, 6, 8, 10, 12, 14, 16) were taken on 12 June 2018.

Habitat	***Cirsium* meadow**				***Phalaris* marsh**				**Short-sedge fen**				***Eriophorum* mire**			
Plot No.	1		2		3		4		5		6		7		8	
Area (m)	4×4		4×4		2.5×6		2.5×6		5×5		5×5		5×5		5×5	
Relevé No.	1	2	3	4	5	6	7	8	9	10	11	12	14	14	15	16
Number of species	43	41	38	34	16	16	11	14	29	24	23	24	13	12	11	10
Diagnostic species of the class *Molinio-Arrhenatheretea* and ass. *Holcetum lanati*																
Carex brizoides	10	12	10	15	7	8	.	.	+	+	8	1	.	.	.	.
Lathyrus pratensis	+	1	1	1	+	1	.	.	r	+	.	.	.	.	.	.
Rumex acetosa	+	+	1	1	.	r	.	.	.	r	r	r	.	.	.	.
Holcus lanatus	1	+	+	1	.	.	.	.	.	.	+	r	.	.	.	.
Cirsium palustre	r	r	1	+	.	.	.	.	.	.	r	+	.	.	.	.
Lychnis flos-cuculi	+	+	+	r	r	+	.	.	.	.	.	.	.	.	.	.
Alopecurus pratensis	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus acris	+	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.
Achillea ptarmica	.	r	r	.	.	.	.	.	.	.	+	+	.	.	.	.
Galium palustre	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.
Diagnostic species of the alliance *Calthion palustris* and ass. *Polygono bistortae-Cirsietum heterophylli*																
Bistorta major	1	6	9	7	2	5	.	+	10	10	8	5	.	.	.	.
Galium uliginosum	4	1	4	1	+	+	r	+	1	1	.	r	.	.	.	.
Cirsium heterophyllum	5	6	4	7	.	.	.	.	2	1	+	+	.	.	.	.
Agrostis capillaris	5	10	5	7	r	.	.	.	.	.	.	.	.	.	.	.
Angelica sylvestris	.	.	.	.	.	.	r	r	1	3	.	r	.	.	.	.
Scirpus sylvaticus	.	.	.	.	+	1	10	25	.	.	.	.	.	.	.	.
Hypericum maculatum	3	6	6	4	.	.	.	.	.	.	.	.	.	.	.	.
Crepis paludosa	+	3	r	+	.	.	.	.	.	.	.	.	.	.	.	.
Caltha palustris	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.
Diagnostic species of the ass. *Phalaridetum arundinaceae*																
Lysimachia vulgaris	r	r	.	.	1	1	r	1	.	.	.	r	.	.	.	.
Phalaris arundinacea	r	.	.	.	75	50	85	40	.	.	.	.	.	.	.	.
Scutellaria galericulata	.	.	.	.	+	+	.	r	.	.	.	.	.	.	.	.
Diagnostic species of the class *Scheuchzerio palustris-Caricetea nigrae*																
Potentilla erecta	5	8	1	+	r	r	.	.	1	3	10	8	3	3	2	3
Carex nigra	1	3	.	r	.	.	.	.	15	6	3	+	4	1	+	+
Agrostis canina	.	.	.	.	.	.	.	.	r	3	2	7	2	7	4	6

Table 1. Continued.

Habitat	***Cirsium* meadow**				***Phalaris* marsh**				**Short-sedge fen**				***Eriophorum* mire**			
Plot No.	1		2		3		4		5		6		7		8	
Area (m)	4×4		4×4		2.5×6		2.5×6		5×5		5×5		5×5		5×5	
Relevé No.	1	2	3	4	5	6	7	8	9	10	11	12	14	14	15	16
Number of species	43	41	38	34	16	16	11	14	29	24	23	24	13	12	11	10
Viola palustris	.	.	.	.	.	.	.	.	+	r	+	r	+	r	r	.
Carex rostrata	.	.	.	.	.	.	.	.	20	10	.	.	1	r	.	.
Eriophorum angustifolium	.	.	.	.	.	.	.	.	1	1	+	r	.	.	.	.
Carex panicea	+	r	.	.	.	.	.	.	.	.	r	.	.	.	.	.
Potentilla palustris	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.
Diagnostic species of the class *Oxycocco-Sphagnetea*																
Eriophorum vaginatum	.	.	.	.	.	.	.	.	.	.	.	.	30	20	35	13
Other species																
Filipendula ulmaria	9	10	12	15	5	8	r	2	2	3	r	.	.	.	.	.
Festuca rubra	3	3	5	7	.	.	.	.	2	1	5	2	.	r	r	r
Luzula multiflora	+	+	r	r	.	.	.	.	r	.	1	+	+	.	+	+
Sanguisorba officinalis	4	7	3	1	.	.	.	.	3	4	8	7	r	.	.	.
Deschampsia cespitosa	5	5	8	8	.	+	.	.	2	2	2	4	.	.	.	.
Vicia cracca	+	+	+	+	+	.	r	r	r	+	.	.	.	.	.	.
Juncus filiformis	.	.	.	.	.	.	.	.	20	25	15	20	3	6	5	+
Peucedanum palustre	.	.	.	.	.	.	.	.	6	6	8	8	3	8	3	8
Chaerophyllum hirsutum	2	5	3	5	r	+	.	.	r	.	.	.	.	.	.	.
Pimpinella major	1	1	1	4	.	.	.	.	1	2	.	.	.	.	.	.
Veronica chamaedrys	1	1	2	1	.	.	.	.	r	r	.	.	.	.	.	.
Molinia caerulea	.	.	.	.	.	.	.	.	.	.	.	.	13	15	10	10
Aegopodium podagraria	.	.	4	6	r	4	.	.	.	.	.	.	.	.	.	.
Carex pallescens	3	5	+	1	.	.	.	.	.	.	.	.	.	.	.	.
Holcus mollis	1	3	+	1	.	.	.	.	.	.	.	.	.	.	.	.
Juncus effusus	1	1	.	.	1	2	.	.	.	.	.	.	.	.	.	.
Alchemilla sp.	2	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Achillea millefolium	r	+	r	r	.	.	.	.	.	.	.	.	.	.	.	.
Anemone nemorosa	.	.	.	.	.	.	.	r	r	.	r	+	.	.	.	.
Avenella flexuosa	.	.	.	.	.	.	.	.	.	.	.	.	r	+	r	r
Cardaminopsis halleri	r	r	+	r	.	.	.	.	.	.	.	.	.	.	.	.
Epilobium palustre	.	.	.	.	.	.	r	r	r	.	.	r	.	.	.	.

Table 1. Continued.

Habitat	*Cirsium* meadow				*Phalaris* marsh				Short-sedge fen				*Eriophorum* mire			
Plot No.	1		2		3		4		5		6		7		8	
Area (m)	4×4		4×4		2.5×6		2.5×6		5×5		5×5		5×5		5×5	
Relevé No.	1	2	3	4	5	6	7	8	9	10	11	12	14	14	15	16
Number of species	43	41	38	34	16	16	11	14	29	24	23	24	13	12	11	10
Poa pratensis	r	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Stellaria graminea	r	r	r	r	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium holosteoides subsp. *triviale*	r	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.
Trifolium pratense	.	r	r	r	.	.	.	.	.	.	.	.	.	.	.	.
Poa chaixii	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.
Aconitum plicatum	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.
Campanula patula	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex ovalis	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dactylis glomerata	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galeopsis tetrahit	.	.	.	.	.	.	r	r	.	.	.	.	.	.	.	.
Mentha arvensis	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Succisa pratensis	.	.	.	.	.	.	.	.	.	.	r	r	.	.	.	.
Urtica dioica	.	.	.	.	.	.	r	+	.	.	.	.	.	.	.	.
Viola tricolor	r	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.

Species present in small abundances (as indicated by symbol r) only in one relevé (relevé No. given in brackets): *Trifolium spadiceum* (1), *Ajuga genevensis* (3), *Tanacetum vulgare* (7), *Avenula pubescens* (9), *Briza media* (11).

Table 2. Cover of plant functional groups on permanent plots in the floodplain of Jedlový Potok in early summer 2017 and 2018. Even relevés (No. 1, 3, 5, 7, 9, 11, 13, 15) were taken on 28–29 June 2017; odd relevés (No. 2, 4, 6, 8, 10, 12, 14, 16) were taken on 12 June 2018.

Habitat	***Cirsium* meadow**				***Phalaris* marsh**				**Short-sedge fen**				***Eriophorum* mire**			
Plot No.	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
Relevé No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**14**	**14**	**15**	**16**
Moss layer	0	0	0	0	0	0	0	0	0	0	0	5	60	50	75	70
Sphagnales	0	0	0	0	0	0	0	0	0	0	0	5	60	50	75	70
Other mosses	0	0	0	0	0	0	0	0	0	0	0	+	r	r	1	1
Herb layer	70	95	80	90	90	75	95	65	90	80	70	60	60	60	60	40
Poaceae	16	22	18	24	75	50	85	40	6	7	9	13	13	22	14	16
Cyperaceae	14	20	10	16	7	9	10	25	35	16	11	1	5	1	0	0
Other monocots	1	1	0	0	1	2	0	0	21	26	16	20	33	26	40	13
Dicots	37	57	53	53	8	19	0	3	28	34	36	35	8	13	5	11
Total cover	**70**	**95**	**90**	**90**	**90**	**75**	**95**	**65**	**90**	**80**	**70**	**60**	**70**	**60**	**80**	**75**

by the presence of *Lysimachia vulgaris* and *Scutellaria galericulata* and absence of long-term flooding (cf. Fig. 2), which excludes disturbances by water flow. The *Phalaris* marsh is a type of the tall grass marsh communities described by Bufková et al. (2005).

The short-sedge fen had the second greatest species richness with a total of 30 phanerogams, which included 18 dicots forming about 30% total cover (Table 1, 2). The community shared many species with the *Cirsium* meadow including the tall herbs *Cirsium heterophyllum*, *Bistorta major* and *Filipendula ulmaria,* which formed conspicuous seasonal colour aspects. Several phanerogam species were diagnostic of the class *Scheuchzerio palustris-Caricetea nigrae* Tüxen 1937. The presence of short-sedge species and the fragmentary development of the moss layer indicated its closeness to the association *Caricetum nigrae* Braun 1915. The habitat resembled the short-sedge mire of the *Carex rostrata–C. canescens* community as described by Bufková et al. (2005). The high representation of *Juncus filiformis* and *C. brizoides* is considered a sign of degradation caused by the previous drainage and abandonment.

The *Eriophorum* mire hosted the smallest number of species of the four habitats. The community was formed mainly by two strong dominants, *E. vaginatum* and *Molinia caerulea*, and a few additional species in small abundances that occurred also in the neighbouring habitats. It was the only one of the four habitats with a well-developed moss layer, formed mostly by *Sphagnum* species. *Eriophorum vaginatum* might indicate a transition toward an open bog of the association *Eriophoro vaginati-Sphagnetum recurvi* Hueck 1925; another species diagnostic of this association, *Vaccinium uliginosum*, was absent from the permanent plots but occurred closer to the neighbouring waterlogged spruce forest. On the other hand, the high dominance of *M. caerulea* indicated pronounced fluctuations of the groundwater table in the past. The community is probably identical with the tall grass fen dominated by *Molinia caerulea* according to Bufková et al. (2005).

Ideally, the relevés should be taken prior the restoration for at least three years. However, it was not possible in this study. A question therefore remains how much the relevés reflect the state of the vegetation before the restoration. It seems that they do because vegetation changes are usually identifiable after a longer time, in some cases even after decades (Prach 1993, 2008) while inter-annual differences rather reflect meteorological differences. The two years after the restoration were exceptionally dry, which most probably weakened the immediate restoration effect.

Conclusion

The vegetation of the Jedlový Potok floodplain includes typical plant communities of the Vltavský Luh wetland complex. The sequence of the unmanaged habitats extending from the stream bank further away, i.e. the *Phalaris* marsh, the short-sedge fen, and the *Eriophorum* mire, represent a good example of the local wetland zonation, encompassing both the regularly-flooded riparian zone and the marginal peatland zone. The wet *Cirsium* meadow, resulting from the joint effects of water regime and extensive mowing, adds both to the species and habitat diversity of the area. Although the communities bear signs of degradation such as fairly high covers of *Carex brizoides*, *Juncus filiformis*, and *Molinia caerulea*, resulting from the previous drainage and abandonment, they have preserved their characteristic physiognomy and species composition, which will hopefully be further supported by the restored natural water regime of the stream.

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