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Monitoring of the restored streams in the Vltavský Luh (Šumava National Park)†

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Abstract
The area of the Vltavský Luh (lower part of the Teplá Vltava stream and the Studená Vltava stream catchments) has been seriously altered by amelioration of mires and wet meadows and channelisation of streams draining them. Removal of the old drainages and restoration of the channelised sections of streams has been implemented to recover the hydrological regime of the area. Lower sections of the three streams, Hučina, Jedlový Potok and Žlebský Potok, have been restored in 2013–2015. The associated research is focused on the monitoring and evaluation of the success of these restorations. Main objectives are (i) to describe the colonisation of the restored stream channels by aquatic macroinvertebrates and the development of their assemblages in relation to flow and substratum conditions, (ii) to compare macroinvertebrate and plant communities before and after restoration, and (iii) to analyse the dynamics of vegetation changes in relation to the water regime and plant growth forms.

Key words: restoration, macroinvertebrates, vegetation, hydrology, Bohemian Forest

Introduction

Human activities in the Bohemian Forest (Šumava in Czech) caused extensive drainage of many peat-bogs, spruce mires, and other wetlands during the past two centuries. Inventories carried out after establishing the Šumava National Park in 1991 showed that almost 70% of mires have been affected and the past drainage is one of the most serious issues in mire conservation in this NP (e.g. Bufková et al. 2010, Bufková 2013). In consequence, alluvial woodland and tall-herb communities, some of which are probably relics of the Early Holocene and host rare species of both plants and associated invertebrates (e.g. Sádlo & Bufková 2002, Jaroš & Spitzer 2013), were gradually substituted by often monotonous communities of stronger plant competitors inhabited by generalist species (Bufková et al. 2006). Such an extent of overall wetland degradation stimulated the restoration programme, which has been

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implemented since 1999. It has mainly aimed at the recovery of drained mires and general improvement in water regime in the landscape. The restoration is based on the final water level concept, when underground water level is shifted to that before the drainage. In this manner, the most valuable wetland complexes have been restored including, in particular, Modravské Slatě and Vltavský Luh. Up to now, almost 500 hectares of peat-bogs and mires have been restored and 60 kilometres of drainage channels have been blocked (Bufková et al. 2010, Bufková 2013). The restoration programme is closely linked to ongoing research, outputs of which allow for assessing the effectiveness of the implemented measures.

However, water regime of wet meadows and fens, as well as spruce mires in the Vltavský Luh has been seriously altered also by the channelisation of streams that drain them. Therefore, restoration of the streams was undertaken as a follow-up to the above programme of mire restorations. The ongoing restoration activities have been focused on the renewal of both hydrological and morphological regimes of these streams leading also to the recovery of wet meadows and mires in the catchments. The lower part of the Hučina stream (a right tributary to the Studená Vltava stream near Černý Kříž) was restored in 2013. On the basis of the vegetation and water flow during spring snow melting, the course of the original stream was reconstructed; thus, a new meandering stream channel was constructed in the original bed of the stream. The precedent straightened and entrenched stream channel and old drainages in its environs were filled up by soil and several parts of this channel were modified into pools. The 1.2-km long channelised section of the Hučina stream was thus extended to the length of 1.7 km. Similar restoration is carried out in the lower sections of the Žlebský Potok and Jedlový Potok streams (tributaries to the Teplá Vltava stream near Dobrá) in 2015.

The associated research and monitoring is focused on the development of benthic communities in the restored streams and the vegetation changes in relation to changes in water regime in the floodplain. The main objectives are:

(i) to describe the colonisation of the restored streams by aquatic macroinvertebrates and the development of new communities in relation to flow, water chemistry and substratum conditions (all three restored streams);

(ii) to compare the macroinvertebrate communities inhabiting the Žlebský Potok and Jedlový Potok streams before and after restoration;

(iii) to describe vegetation development in the floodplains before and after restoration;

(iv) to evaluate the success of the restorations by comparing the macroinvertebrate and plant communities to those of undisturbed habitats.

Materials and methods

Project duration

Monitoring of aquatic macroinvertebrates in the Hučina stream has commenced in November 2013 and has been planned for five years (i.e. till November 2018). Monitoring of macroinvertebrates of the Žlebský Potok and Jedlový Potok streams before restoration has been carried out from November 2014 to autumn 2015. The restored Žlebský Potok and Jedlový Potok streams will be monitored for three or five years.

Monitoring of vegetation started in 2011 in the Hučina stream floodplain, i.e. three years before its restoration. Vegetation of the floodplains of the Žlebský potok and the Jedlový potok is being described prior to their restoration in 2015. The follow-up monitoring is planned for five years at a minimum.

Site and method description

Macroinvertebrates

Four sampling sections, three sections in the restored part of the stream and one original section upstream the restored ones, are investigated in the Hučina stream and one more section is located in the Studená Vltava stream below the confluence with the Hučina stream. The three sampling sections on the restored part of stream reflect different types of channels and aquatic habitats. The upper sampling section is located on the wet meadow (the former mire) and represents widely meandering channel with dynamic pool-riffle sequences and substratum (Fig. 1). Bottom substratum is fine gravel and sand and partly clay. The middle sampling section is relatively narrow flowing through spruce forest and restored spruce mire, where the stream is connected with waterlogged *Sphagnum* depressions (Fig. 1). Bottom substratum is sand and fine gravel. The lower section is located below railway and road bridges where the stream channel is entrenched due to its crossing with railway and road (Fig. 1). The channel is meandering, but more stable than in the upper part of the restored stream and predominantly fine-gravel stream bottom is stabilised by quarry stone of about 10 cm in diameter. The two remaining sections, in the Hučina stream above its restored part and in the Studená Vltava stream (Fig. 1), are investigated as the nearest running water habitats hosting possible source populations of invertebrates for colonisation of the restored Hučina stream.

In the Žlebský Potok and Jedlový Potok streams, two sampling sections are investigated before the restoration beginning. The upper section represents the entrenched channel with natural bottom substratum in the Žlebský Potok stream and the paved artificial bottom covered by a layer of gravel and fine sediments in the Jedlový Potok stream. The lower section of both streams represents narrow, deeply entrenched channel with clearly sandy substratum. After the restoration, a similar sampling design as in the Hučina stream with three sampling sections is planned.

At each sampling section, three mesohabitats, riffle, run and pool, are investigated. Macroinvertebrates are sampled semiquantitatively using a hand net with 0.5 mm mesh size. At each mesohabitat, altogether five approx. 25×25 cm plots are sampled and merged into one sample characterising one mesohabitat. Macroinvertebrates are collected also quantitatively by metal strainer with about 0.8 mm mesh size to find all species inhabiting the sampling sections. Adults of Ephemeroptera, Plecoptera and Trichoptera are collected by sweeping of riparian vegetation.

Prior to sampling of each plot, water depth and velocity are measured using a Flo-Mate flow metre (Model 2000; Marsch-McBirney, Frederick, MD, USA). Bottom substratum at each mesohabitat is estimated as the proportions of cover by different grain sizes of mineral substratum (clay <0.1 mm, sand 0.1–2 mm, fine gravel 2–16 mm, coarse gravel 16–64 mm, stones 64–256 mm and boulders >256 mm) and particulate organic matter (Fine Particulate Organic Matter <1 mm, Coarse Particulate Organic Matter >1 mm). Proportions of the three mesohabitats at each sampling section are estimated. Before sampling, water temperature, pH, conductivity, and dissolved oxygen content are measured in situ using a portable instrument (HACH HQ40d; HACH Co., Loveland, CO, USA) at each sampling section. Samples of water for water chemistry analyses are analysed from all four sampling sections in the Hučina stream. The following parameters are analysed: alkalinity, Dissolved Organic Carbon, total P, NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, Al and Fe forms. Water temperature, discharge, conductivity and pH are continuously measured in the Hučina stream near the road bridge (Fig. 1).

Vegetation

In order to document the vegetation prior to the stream restoration, a map of the habitat types *sensu* Chytrý et al. (2010) was made for the Hučina stream floodplain (Fig. 2). Background information included local topographic map, ortophotograph, and the map of forest inventory, provided by the Administration of the Šumava National Park. Borders of vegetation units were recorded in the field using an Ashtech GPS Magellan mobile mapper 10. The data were further processed using the ArcGIS 9.2 software. The field survey revealed that the character of vegetation differed among three elevation zones. In the highest elevation zone, which is dry enough to allow access to machinery, the original forest has been clear-felled and replaced by spruce plantations. In the intermediate elevation zone, the species composition of the upper tree layer and understorey correspond to the presumed original habitats. There are numerous fallen trees of intermediate age there, as well as dense spruce stands of all sizes from the herb up to lower tree layers, which presumably originated by natural regeneration. These features indicate that there was no management in this zone for several decades, probably as from World War II, and selection cutting was applied in the preceding period. The lowest elevation zone, extending in the central part of the floodplain, is covered with monodominant stands of *Carex brizoides*, in which other species of wet meadows are only sparsely admixed. This state again indicates absence of management over several decades and degradation resulting from drainage.

The most valuable communities of the area occur in the intermediate elevation zone. They include birch mire forest (association *Vaccinio uliginosi-Betuletum pubescentis* Libbert 1933), pine mire forest with *Vaccinium* (ass. *Vaccinio uliginosi-Pinetum sylvestris* Kleist 1929), pine forest of continental mires with *Eriophorum* (ass. *Eriophoro vaginati-Pinetum*

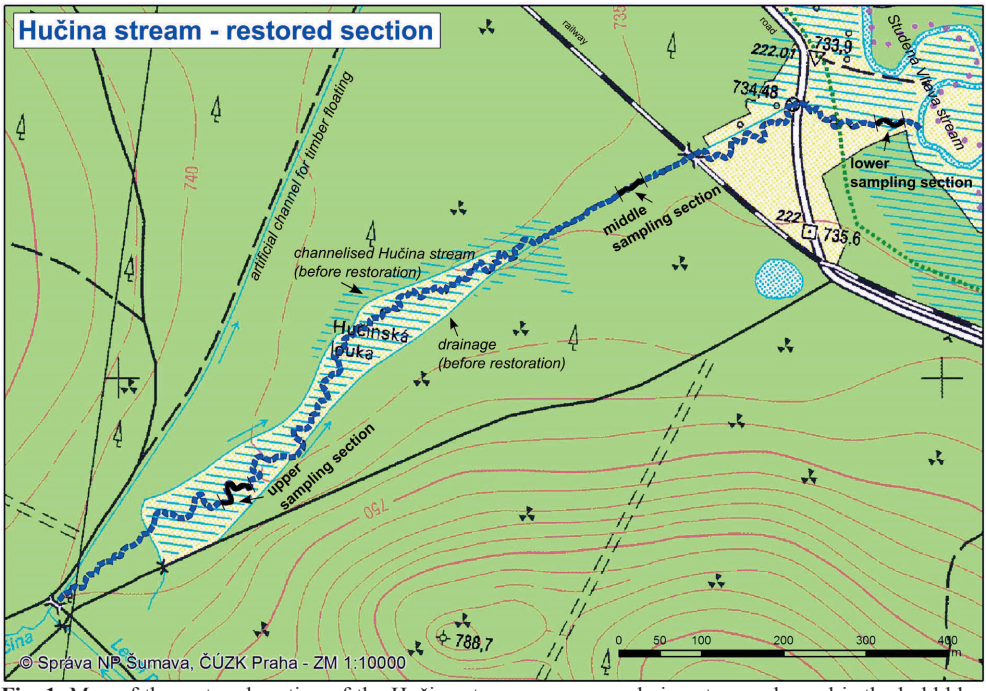

Fig. 1. Map of the restored section of the Hučina stream; new meandering stream channel is the bold blue dotted line.

sylvestris Hueck 1931), and *Pinus rotundata* bog forest (ass. *Vaccinio uliginosi-Pinetum rotundatae* Oberdorfer 1934) using the nomenclature according to Chytrý et al. (2010). They are mostly located in the downstream part of the floodplain where the decrease of

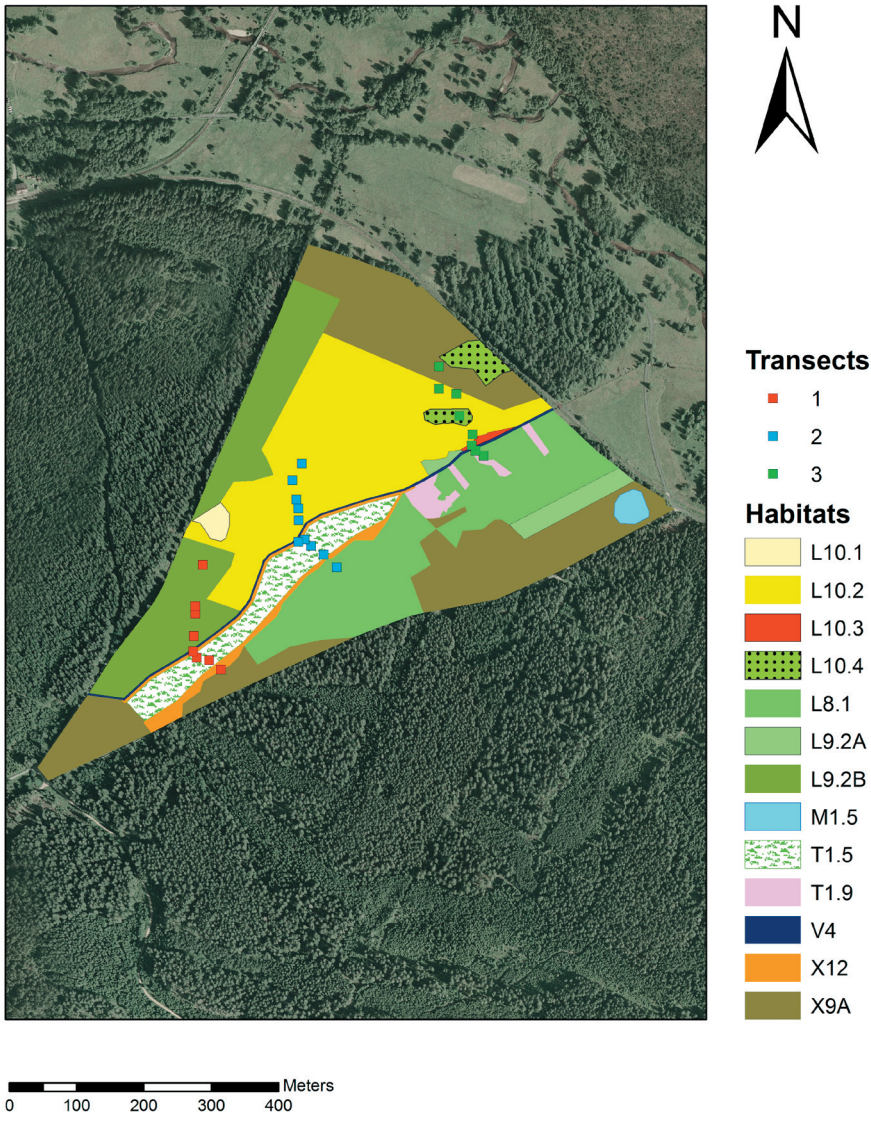

Fig. 2. Map of main habitat types of the Hučina floodplain. Codes are given according to the Habitat Catalogue of the Czech Republic (Chytrý et al. 2010). L10.1 – Birch mire forest; L10.2 – Pine mire forest with *Vaccinium*; L10.3 – Pine forest of continental mires with *Eriophorum*; L10.4 – *Pinus rotundata* bog forest; L8.1 – Boreo-continental pine forest; L9.2A, L9B – Bog spruce forest; M1.5 – Reed vegetation of brooks; T1.5 – wet *Cirsium* meadow; T1.9 – Intermittently wet *Molinia* meadow; V4 – Macrophyte vegetation of water streams; X12 – Stands of early successional woody species; X9A – Forest plantations of allochthonous coniferious trees.

water table was smallest. They presumably represent fragments of habitats that formerly covered larger areas of the floodplain.

In order to follow vegetation changes after the stream restoration, permanent plots were established along three transects laid across the Hučina stream floodplain perpendicular to the stream. Transect 1 was laid in the upper part of the studied floodplain, Transect 2 in the middle, and Transect 3 in the lower part (Fig. 2). Altogether 12 plots of an area of 4×4 m were positioned in the central open part of the floodplain and 14 plots having 10×10 m were placed in the surrounding forested parts. Boreholes were installed at a border of each plot to a depth of 1 m. Each year since 2011, vegetation relevés were taken from all plots in early summer and the water level was measured in the boreholes. In 2011, soil samples were taken from the surface soil horizon in all plots. The soil samples were analysed for the content of organic matter, estimated as the loss on ignition at 450°C. The same methodology is envisaged also for the assessment of vegetation of the floodplains of the Žlebský Potok and the Jedlový Potok streams.

Research outputs

The results remain unpublished up to date. Preliminary results of the vegetation survey of the Hučina floodplain before stream restoration are given by Lazárková (2012), Sláma (2012), and Stachová (2015). The monitoring of macroinvertebrates with preliminary results was presented at the Czech and Slovak limnological conference (Rádková et al. 2015).

The project will provide detailed data on the temporal succession of aquatic habitats and benthic invertebrates in the restored streams and vegetation in the floodplain before and after stream restoration. The main outputs of this project will include the assessment of the expected development of benthic communities towards more stable and diverse ones. The vegetation changes will be evaluated considering both the temporal and spatial scales which will presumably differ among the main growth forms (mosses, herbs, graminoids and trees). The results will be also applicable for evaluating the success of ecological restoration implemented by the Šumava NP. If the restoration of these habitats is successful, then the restoration histories can provide valuable background information for restoration of other sites in similar conditions.

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