

Current occurrence of endangered *Pedicularis palustris* L. in the Bohemian-Moravian Highlands and its relation to well-performed management

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Abstract: A hemiparasitic herbaceous plant species, *Pedicularis palustris*, has historically been abundant in most of the Bohemian-Moravian Highlands. Populations of this wetland species decreased dramatically during the twentieth century, due to the gradual abandonment of the traditional use of the landscape. For this reason, *Pedicularis palustris* is now a critically endangered species within the Czech Republic, with the Bohemian-Moravian Highlands being one of the most important and last refuges of this species in Central Europe. A field survey of the current population size was carried out in 30 localities, where the species was known to be located over the last 20 years. The species was confirmed in only nine of them, whereas in the other locations, the species is probably lost due to the succession of vegetation, climate change or change in land use. The importance of well-performed management was found to be crucial for the survival of the remaining populations.

Key Words: biodiversity, plant extinction, degradation of wetlands, nature protection

INTRODUCTION

Pedicularis palustris is a hemiparasitic plant of the *Orobanchaceae* family that uses water and nutrients by haustoria from a wide range of host plants sharing the same habitats (Těšitel et al. 2015). Monocotyledonous plants like grasses and sedges are considered as main hosts (Hrouda 2000), but *Pedicularis palustris* is also able to parasitise on dicotyledons (Petrů and Lepš 2000). The most suitable habitats for this species are transitional mires, moss rich fens, reed beds and tall-sedge vegetation (Hrouda 2000, Chytrý et al. 2011). Seed propagation takes place autochorously and hydrochorously (PLADIAS), which implies the importance of a quality water regime.

There were two subspecies distinguished in the territory of the Czech Republic. Nominotypical subspecies occurs mainly in the Bohemian-Moravian Highlands, and in parts of the Šumava and Slavkovský les, although the occurrence is extremely rare in the rest of the Czech Republic. In addition to the nominotypical subspecies, the North-European subspecies *Pedicularis palustris* subsp. *opsiantha* was recently recorded in northern Bohemia (Krása 2007, Wild et al. 2019). According to Decree No. 395/1992 Sb. the species is classified as a highly endangered plant, and according to the Red List of Endangered Plants of the Czech Republic, it is classified as critically endangered (Grulich and Chobot 2017). The species is also evaluated as endangered in other central European countries (Niklfeld and Schratt-Ehrendorfer 1999, Eliáš et al. 2015).

In the twentieth century, the species was very abundant in the Bohemian-Moravian Highlands (Rybníček 1974). However, due to the change in landscape management and the adjustment of the water regime by drainage, large populations have been reduced to a critical level (Čech et al. 2014).

The aim of this article is to survey the populations of *Pedicularis palustris* in the whole Bohemian-Moravian Highlands, evaluate their current abundance in particular localities, assess the consequences of changes in abundance, and assess the possible survival of the species in this region.

MATERIAL AND METHODS

The Bohemian-Moravian Highlands are located in the central part of the Czech Republic. A total of 30 localities were visited during the vegetation season of 2020, where the species was known to be located in the last 20 years (2000–2019). Data on historical species distribution were obtained from floristic databases (Wild et al. 2019), literature (Rybníček 1974), and personal communication with local experts (E. Ekrťová, F. Lysák, T. Peterka, K. Juříčková). Abundance data were recorded at the localities, where the species was confirmed. Exact numbers of individuals were recorded on a logarithmic scale (individuals, dozens, hundreds or thousands of individuals). Information related to the local conditions and management practice was also noted.

Both the confirmed and unconfirmed findings are summarised, mapped (ESRI ArcGIS Desktop, Figure 1), and discussed in this paper. Based on a link between current and previous abundance and observed management, we recommend here a form of well-performed management for the survival of *Pedicularis palustris*.

RESULTS AND DISCUSSION

Occurrence of *Pedicularis palustris*

In the Bohemian-Moravian Highlands, the species has occurred in dozens of localities in the second half of the twentieth century (in 40 European mapping quadrates, Čech et al. 2014). Due to the abandonment of the traditional use of landscape and the adjustment of the water regime by drainage, there was a drastic decrease in the population up to 2000. Since 2000, the species have been recorded in the Bohemian-Moravian Highlands in only 23 localities (twelve quadrates of the European mapping network). In most localities, the populations showed a declining tendency.

Our own field survey of *Pedicularis palustris* sites in 2020 confirmed its occurrence in only nine localities in seven mapping quadrates of the European mapping network (Table 1, Figure 1). Stable populations during the last 20 years were found for Řeka, V Lisovech, Chvojnov, Na Oklice, Ratajské rybníky, Vílanecké rašeliniště and Kladinský potok. It should be mentioned here, that in the locality Vílanecké rašeliniště, the habitat including a population of *P. palustris* was restored by removing dense vegetation consisting of tall sedges. In the whole study region, two localities (Chvojnov and Na Oklice) had the most numerous populations. Also, in these locations the species was purposefully supported by appropriate management, which led to an increase in the abundance of the population. At present, the populations of the species exceed a thousand individuals and significantly affect the composition of vegetation and increase biodiversity. Similar numbers of individuals as in the past have been verified on Řeka mire meadow, where variation in the occurrence of individuals within the locality were observed, depending on the disturbances caused by heavy mechanisation during mowing. The occurrence in Kladinský potok can also be described as stable despite drier a habitat compared to other localities.

In the south-eastern subregion of Velké Meziříčí, last populations of *P. palustris* were found 15 years ago, and despite regular mowing management could not be restored (localities: Bohdalov, Těšíkův mlýn). In the north-eastern subregion of the Žďárské vrchy Hills, *P. palustris* was found a few years ago in the localities of Bahna, Mokřadlo, Volákův kopec and Radostínské rašeliniště. The situation in the Žďárské vrchy Hills Protected Landscape Area is critical, as the species is probably preserved in only three localities. Although it is possible that there will be new findings in the future, the probability is rather small due to the size and conspicuousness of the species. The last discovered locality is probably Medlovský rybník Pond from August 2017 (Roleček, personal communication). This locality consists of wetland vegetation on the edge of the pond and is sufficiently humid and slightly disturbed by tourists and fishermen. The example of this locality shows how positively the fluctuation of the water level can affect the distribution of the species. *P. palustris* was not confirmed in either of the localities of the south-western part of the study region (U Zabitého and Chytrov).

*Table 1 List of localities with abundance of *Pedicularis palustris* observed in the field in 2020 and obtained for the previous twenty years. Explanatory notes: “<” “population decrease, “>” “population increase, “=” “stable population*

Number (Figure 1)	Locality	Relative abundance 2000–2019	Relative abundance 2020	Last occurrence	Population
1	Chvojnov	100–1000 pcs	>1000 pcs	-	>
2	Nad Svitákem	<10 pcs	not confirmed	2008 (Juříčka J.)	<
3	Na Oklice	10–100 pcs	100–1000 pcs	-	>
4	Kladinský potok	10–100 pcs	10–100 pcs	-	=
5	U Potoků	<10 pcs	not confirmed	-	<
6	Vílanecké rašeliniště	<10 pcs	10–100 pcs	-	>
7	V Lisovech	10–100 pcs	100–1000 pcs	-	>
8	Kaliště	<10 pcs	not confirmed	-	<
9	Chytrov	10–100 pcs	not confirmed	-	<
10	U Zabitého	<10 pcs	not confirmed	2013 (Holá E.)	<
11	U Hájenky	10–100 pcs	<10 pcs	-	<
12	Těšikův mlýn	10–100 pcs	not confirmed	2010 (Lysák F.)	<
13	Bohdalov	<10 pcs	not confirmed	2002 (Lysák F.)	<
14	Medlovský rybník	no data	10–100 pcs	-	>
15	Radostínské rašeliniště	10–100 pcs	not confirmed	2018 (Peterka T.)	<
16	Řeka	100–1000 pcs	100–1000 pcs	-	=
17	Mokřadlo	10–100 pcs	not confirmed	2019 (Špinar J.)	<
18	Velký Černý	<10 pcs	not confirmed	2015 (Pecharová E.)	<
19	Utopenec	<10 pcs	not confirmed	2018 (Gutzerová N.)	<
20	Volákův kopec	<10 pcs	not confirmed	2013 (Peterka T.)	<
21	Bahna	10–100 pcs	not confirmed	2017 (Peterka T.)	<
22	Ratajské rybníky	100–1000 pcs	10–100 pcs	-	<

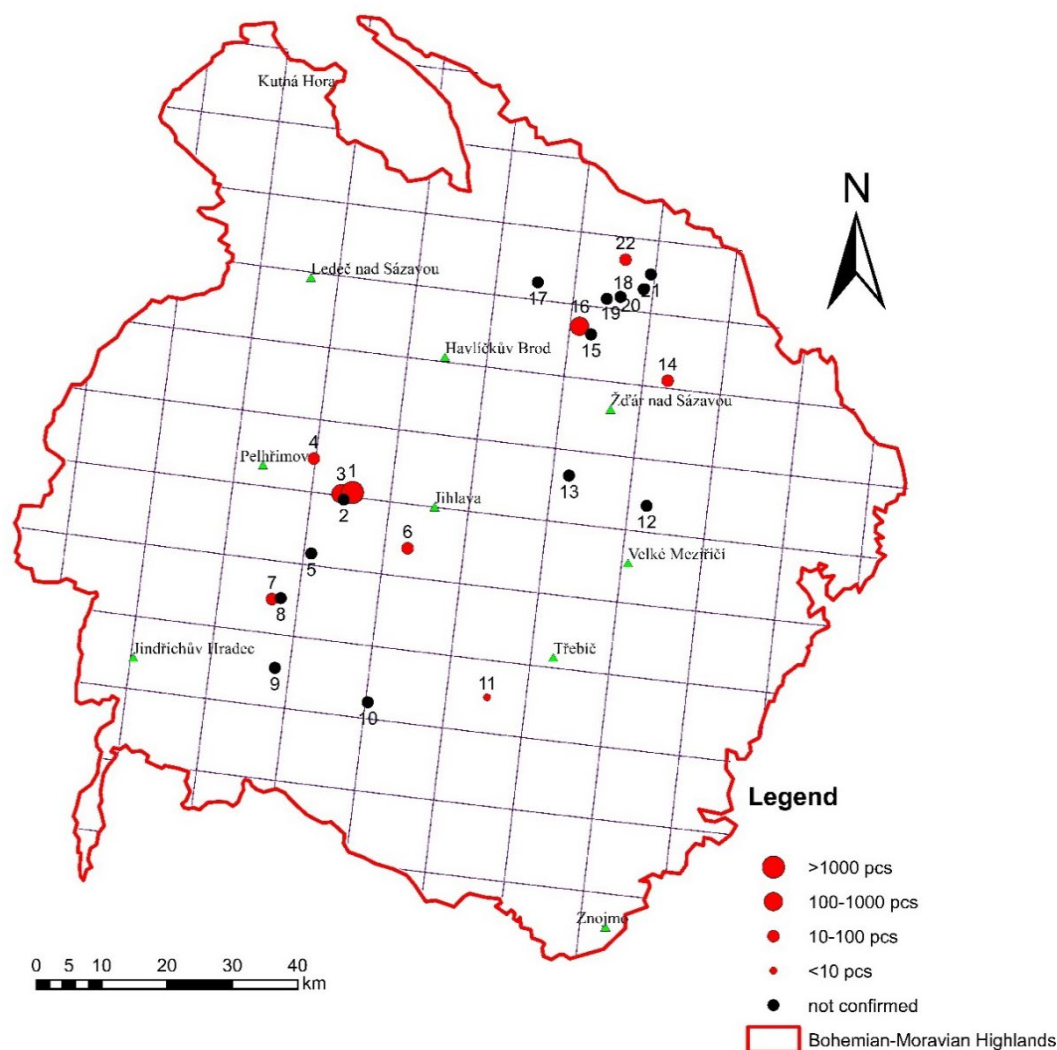
Importance of management

The current decline in populations, or extinction, is very evident in the localities in Žďárské vrchy, despite the mowing and removal of organic matter. In contrast, localities from the western part of the territory show a better condition than twenty years ago. The most obvious situation is at the Chvojnov locality, where the degraded part of the locality was revitalised. In the place of reeds or almost ruderal vegetation there are very high-quality moss-rich fens, and the population of *Pedicularis palustris* has expanded to become one of the largest in the Czech Republic. In a larger population, the importance of an ecological engineer (Decler et al. 2014) in influencing host plants and suppressing competition is seen, which leads to the promotion of biodiversity.

The increase in populations in these localities is linked to the management carried out. In addition to mowing and removing biomass, vegetation around the mother plants is also excavated here. This effect is very significant, for example Petrů and Lepš (2000) have shown that most seedlings occur within 0.3 m of the mother plant, and if plants are left uncut, a rather limited seed shadow is created (Fenner 1992). Several historical records also show the occurrence of the species in ruts from heavy mechanization. This is similar to the Řeka locality, where the species spreads mainly in an intensively mowed meadow out of the main part of the endangered locality.

In addition, important prerequisites for the occurrence of the species are a sufficient seed bank (strict requirement), sufficient moisture and low nutrient content in the locality (Jensen and Schmidt 2000). In such a mode, the species is able to occur without management. When moisture decreases and nutrients increase in the locality, *Pedicularis palustris* cannot compete with higher plants like other hemiparasitic plants, which are bound to nutrient-poor habitats (Těšitel et al. 2015).

Figure 1 Current occurrence of *Pedicularis palustris* in Bohemian-Moravian Highlands



The extent and method of management is fully dependent on change of the two factors mentioned above, which must be replaced and approached for each site individually. While in some localities it is enough to reduce the height of the cut vegetation, in some places management cannot be done without disturbing the surface. In all cases, it is necessary to leave at least part of the mother plants uncut for producing seeds. If the capsules are open, the plants can be mown, and the seeds will be distributed by mowing tools. The disadvantage of this method is the gradual ripening of plants, which lasts from June to August (Hrouda 2000).

Without adequate management, populations in some localities may become extinct during drier seasons, as occurred in the dry episode 2014–2019. Combined with the low lifespan of the seed bank, the future of the species is uncertain without regular management. Consequently, it would be appropriate to undertake greater management interventions in the form of soil removal. Priority should be given to those localities where the last occurrence is reported within a period of less than five years from the present, due to the short lifespan of the seed bank. Positive examples of success are shown by interventions in the localities of Vílanecké rašeliníště, U Hájenky, Chvojnov, Na Oklice and V Lisovech. The following localities are proposed for interventions to restore the population: Bahna, Volákův kopec, Utopenec and Radostínské rašeliníště. All the mentioned localities are mowed, which gives the intended intervention a good precondition for the future state.

CONCLUSION

The updated data on the occurrence of *Pedicularis palustris* has shown how critical the current situation is. Thanks to the dry period that occurred between 2014–2019, it is possible to understand how

quickly endangered species associated with specific conditions can disappear. Compared to the historical occurrence (2000) in 23 localities in twelve mapping quadrates, the occurrence in 2020 was demonstrated in only nine localities in seven mapping quadrates. The occurrence maps created show a reduction of the population across the whole territory.

During the 2020 season, the water level increased in several localities 0.5 m above the ground surface. Precipitation increased and temperatures decreased compared to the previous five years, which were characterised by extremely low precipitation. However, the benefits for other population trends are questionable due to the submerged flowering plants, which have remained under stagnant water for a relatively long time. In the following years, we will discover whether this year's wetting supported the germination of plants from the seed bank. Localities where negative findings were recorded and the historical occurrence is less than five years old are still suitable for *P. palustris* restoration, with continual mowing together with local soil removal or other surface disturbance benefiting the low-competitive species regenerating from seeds. To preserve the species, it is necessary to practise well-established management because specific examples of occurrence in combination with the chosen method of management demonstrate its positive effect.

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