

Local extinctions of threatened species of *Pedicularis* L. in agriculture landscape of southeastern Bohemian-Moravian Highlands

Jan Oulehla¹, Martin Jirousek^{1,2}, Filip Lysak³

¹Department of Plant Biology
Mendel University in Brno
Zemedelska 1, 613 00 Brno

²Department of Botany and Zoology
Masaryk University
Kotlarska 2, 611 37 Brno

³Cyrilov 6, 594 61 Bory
CZECH REPUBLIC

xoulehla@mendelu.cz

Abstract: The general extinction of organisms belongs to significant environmental problems through the world. In addition to the rare species which long-term occurred only on several localities, we face today the problem of a massive retreat of number of species that perhaps seven decades ago were considered to be relatively common. Primarily competitive weak species retreat or local extinct in behalf of the stronger competitive ones, the better adapted to human-modified eutrophic agriculture landscape. Using very detailed local floristic data of *Pedicularis palustris* and *P. sylvatica* north of Velké Meziříčí (southeastern Bohemian-Moravian Highlands), we demonstrate continual retreat of species abundances in two-time periods, recent situation with state approximately twenty years ago. *Pedicularis palustris* was historically known from two localities in the region, both of them disappeared and the species has not been found for more than ten years. *Pedicularis sylvatica* survives only on a third of the sites known from 1990s, with a large decrease in abundances. Multiple factors, eutrophication, abandonment of land, warmer and drier climate periods, unsuitable local-management practices in some cases, speed up significantly the process of local species extinction, within a relatively short time period of twenty years. Similar fate has met also other species of plants or animals in different regions.

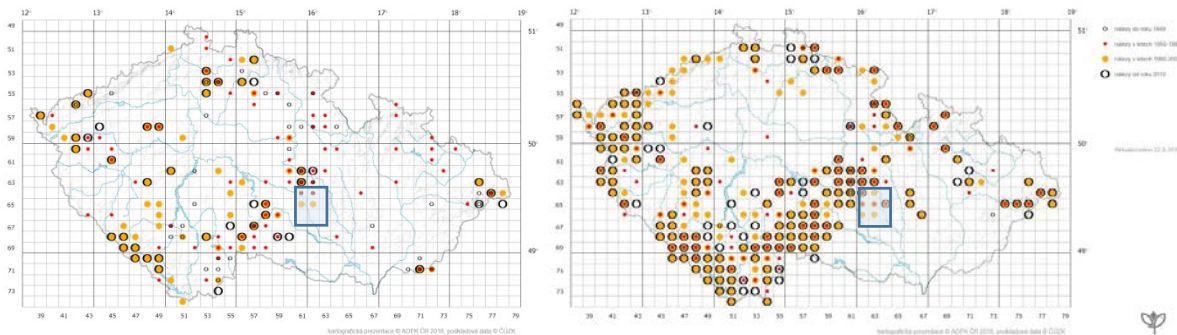
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INTRODUCTION

There are in total four species of *Pedicularis* (*Orobanchaceae* family) in the recent Czech flora, leaving aside *Pedicularis sceptrum-carolinum* which has occurred in the Czech Republic until 1966 (Hrouda 2000, Danihelka et al. 2012). *Pedicularis* species are root hemiparasites that requires light and wet conditions, with low competitive ability. *Pedicularis exaltata* is critically endangered species which survives within the Czech Republic only on one locality in White Carpathians (NPR Porážky). *Pedicularis sudetica* subsp. *sudetica* is endemic subspecies to the Krkonoše Mts (there are other subspecies of *P. sudetica* with arctic circumboreal distribution; Krahulec 2006). Only occurrence of two species, *Pedicularis palustris* and *P. sylvatica*, is documented from more regions of the Czech Republic including southeastern Bohemian-Moravian Highlands (Figure 1).

Both studied species, *Pedicularis palustris* and *P. sylvatica*, are monocarpic perennial non-clonal herbs. Both studied species are classified as endangered species due to the large continuous retreat during last decades. *Pedicularis palustris* is classified as critically threatened species (C1t) according to traditional national criteria used in Red Lists of vascular plants (Grulich and Chobot 2017), whereas as an endangered species (EN) according to international criteria (IUCN 2012; Grulich and Chobot 2017). *Pedicularis sylvatica* still remains as the most numerous species of the genus within the Czech Republic and is classified as endangered species (C2t), and according to IUCN concept as vulnerable species (VU; Grulich and Chobot 2017). All species of *Pedicularis* are on the list of the vascular plants nationally protected by law (Conservation Act no. 114/1992 and Decree no. 395/1992).

Figure 1 Distribution of *Pedicularis palustris* (left map) and *P. sylvatica* (right map) in the Czech Republic based on floristic records (maps taken from ISOP AOPK ČR, 2018). The blue rectangles define the studied area.



Low productive wet habitats as fens, sedge wetlands, wet meadows and submontane acidophilous grasslands are most typical for the occurrence of the studied species (Hrouda 2000, Chytrý 2007). In the region of southeastern Bohemian-Moravian Highlands were these habitats common in the past and also occurrence of both studied species was higher than nowadays (Figure 1). Wetland and grassland habitats were historically used as pastures. After the World War Two, wetlands were mainly drained and transformed into agriculture land as highly productive meadows during the Socialist Czechoslovakia. Recently, they are partly managed and partly abandoned. Eutrophication, drainage and lack of management have resulted in vegetation change, biodiversity decrease and disappearance of both, natural habitats and competitive-weak threatened species in them. Besides *Pedicularis* species also other co-occurring vascular plants (e.g. *Dactylorhiza majalis*, *Parnassia palustris*) or bryophytes (e.g. *Helodium blandowii*, *Paludella squarrosa*) were reported to decrease their populations or totally lost (Lysák 2000, Lysák 2010, Oulehla 2017). More distinct declines of suitable habitat and species occurrences were in lower altitudes (Pelhřimov Region, Velké Meziříčí Region), whereas relatively more pristine species-rich fen localities remained more preserved in higher altitudes of Žďárské Vrchy Hills (Peterka et al. 2014).

Given that the data on frequency of wetland plants were available from the studied region of Velké Meziříčí (Lysák 2000), we are able to demonstrate changes in population sizes of particular threatened plant species after 20 years in great detail. Field notes, knowledge about history of localities and ecology of studied plant species can help us to understand the causes of species population decreases and comment possibilities of their restoration.

MATERIAL AND METHODS

Study area

The studied area is located in the southeastern part of the Bohemian-Moravian Highlands, north of the town of Velké Meziříčí (Figures 2–3). The altitude is around 500–600 meters above sea level. The long-term mean annual temperature is 7–8 °C and long-term average precipitation 600–700 mm (average data for the period 1981–2010 taken from the Czech Hydrometeorological Institute Web Sites: <http://portal.chmi.cz>).

Mires with active peat formation are rare within the region and physiognomically resemble rather slightly acidic fen meadows (*Caricion canescenti-nigrae* alliance). Wet meadows (*Calthion palustris* alliance), formed after drainage of fens, are recently abandoned or inappropriately managed with continuous decreasing of threatened wetland plants including *Pedicularis* species (Oulehla 2017).

Floristic survey

All of the known historical localities of *P. sylvatica* with abundance data were revisited repeatedly at least twice in a year (15 localities; Lysák 2000). Nine of these localities were monitored for four years (2015–2018). Other historical localities of *P. sylvatica* and also *P. palustris* with potential distribution, i.e. with suitable wet conditions and management, were visited only once or rather unsystematically. Only few localities remain recently unseen. The individuals of *P. sylvatica* were counted, together

with vegetation description, recording of co-occurring species, moisture evaluating and management characterisation.

Data presentation

Floristic data regarding to the *Pedicularis palustris* and *P. sylvatica* distribution from field monitoring, literature excerption and web floristic database excerption (PLADIAS 2018) has been mapped (ESRI ArcGIS Desktop; Figures 2–3). Map with historical data contains occurrences of *Pedicularis palustris* and *P. sudetica* recorded by Lysák (2000) and map of current data contains recent occurrences between 2015–2018. The individual localities where the monitoring of *Pedicularis sylvatica* populations took place is commented in detail, discussed and the comparison to the situation 20 years ago is stated.

The nomenclature of vascular plants follows Danihelka et al. (2012) and nomenclature of syntaxa follows Chytrý (2007).

RESULTS AND DISCUSSION

Occurrence of *Pedicularis sylvatica*

Twenty years ago, *P. sylvatica* was known only from 16 localities and other four localities were known as extinct (Lysák 2000).

Population of *P. sylvatica* disappeared from Ústecký pond and Mrázkova meadow (close to Bory village) due to successional change after eutrophication after 1996 and 1980s, respectively (Lysák 2000). The locality of *P. sylvatica* near Kříže (close to Černá village) disappeared due to spruce afforestation after 1994 and in Oudoly (close to Kadolec village) as a result of *Calamagrostis epigeios* and *Scirpus sylvatica* expansion after abandonment of mowing after 1993. The recovery of the species is irreversible on these four localities.

Recently, only seven of the localities of *P. sylvatica* were found as still existing. No new locality was found neither on historical localities nor new localities within the region (Figure 2, Figure 3). The biggest population of *P. sylvatica* in the region was known from Ochoz pond (close to Olší nad Oslavou village), where hundreds of individuals were counted here under the pond dam in 1990s. The population here almost disappeared due to improperly chosen management of mowing. The meadow is partly overgrown by tall grasses (*Calamagrostis canescens*) and partly regularly mulched. The mulch left on the ground cover small plant species and especially it returns the nutrients back to the ecosystem during the decomposition of biomass. Eutrophication led to expansion of competitively strong species (*Rumex obtusifolius*, *Alopecurus pratensis*) at the expense of the original vegetation. The species is no longer present here, but smaller population occurs in a short-grass vegetation northeast of the pond. The latter population is continuously weakened by grass mowing in the inappropriate term of flowering. Only minimum of plants still left and can produce the seeds for next generations. The germination is strongly limited by a dense grass carpet. There is no surface disturbance for attaching the seedlings.

Vegetation succession after abandonment of management led to *P. sylvatica* disappearing in nearby Zátoky locality. Similarly, the occurrence of *P. sylvatica* is no longer known for localities in the vicinity of Chroustov and Sklené nad Oslavou village (at the municipal wells, Vosecký pond and Sklenský pond). Three localities were known in 2002 close to Bohdalov village, where one of them extinct due to expansion of *Calamagrostis* spp., two others (Brychzovský pond and Rendlíčkový stream) were not revisited.

The occurrence of *P. sylvatica* close to Bobrůvka village. The species was historically only sparsely distributed on the land under the municipal wells in the past. It seemed to disappear here as a result of lack of the mowing. This management was later restored and the occurrence of this species was confirmed in 2017, but only one individual was recorded and no individual was found one year later. The loss of the whole population is probably caused due to the inappropriately chosen term of cutting at the time of flowering and absence of grass-carpet disturbances. New seedlings probably appeared from the seed bank from previous years until it was exhausted. In recent years, the drought climate further deteriorates the original wet soil conditions. Historically, there was a stable population of about 50 individuals at Čechův pond margin. This population continuously extinct as a result of the liming, and partly due to depositions left after pond sediments removing. Changes in the ecosystem

biogeochemistry led into eutrophication following by the vegetation succession. There were only 2 individuals found in years 2016 and 2017.

Figure 2 Historical distribution of *Pedicularis palustris* (blue circles) and *P. sylvatica* (red circles) in the studied region.

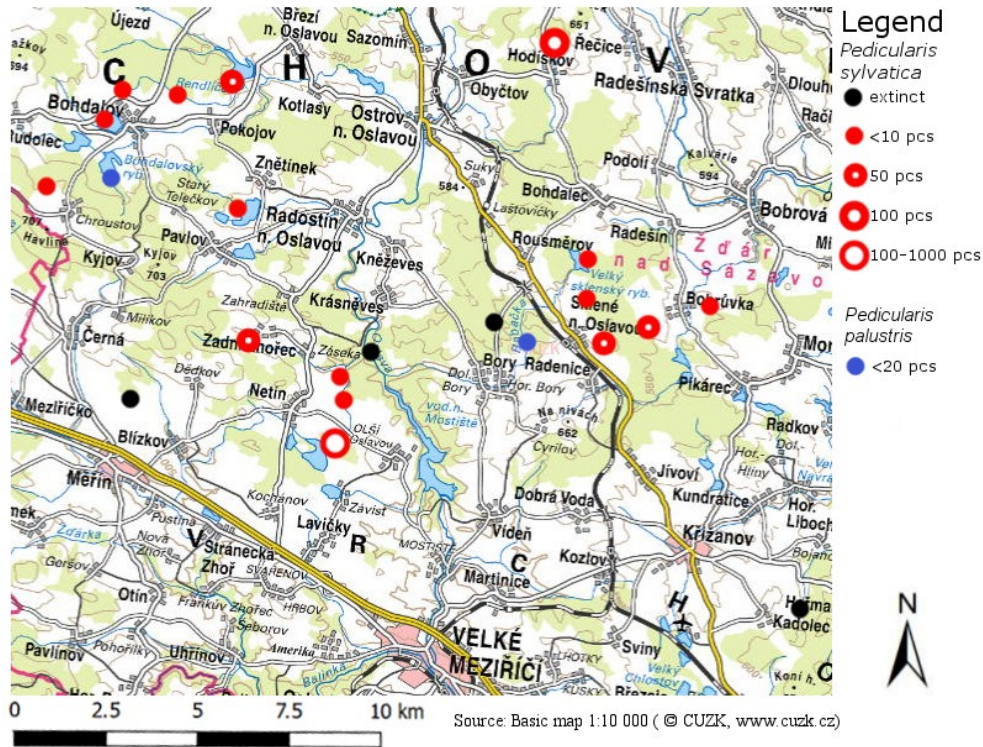
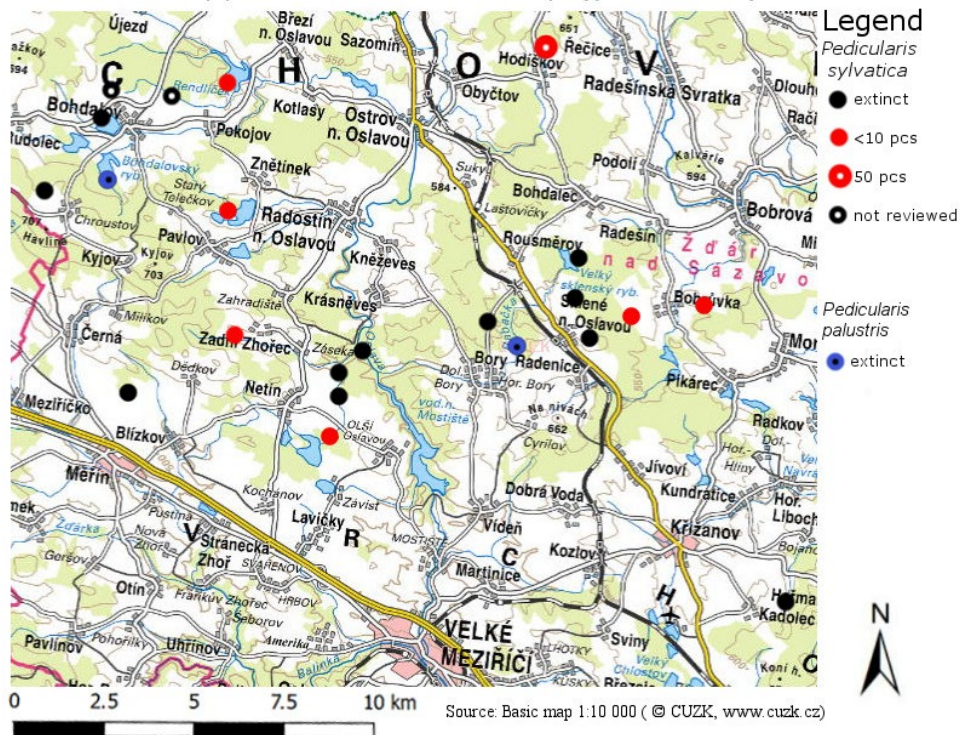


Figure 3 Current distribution of *Pedicularis palustris* (blue symbols) and *P. sylvatica* (red circles) in the studied region



One of the few preserving populations can be found close to Znětínský pond (close to Znětínek village) with several individuals, contrary to dozens individuals known 20 years ago. There is also the biggest occurrence of *Taraxacum nordstedtii* in the region north from Velké Meziříčí.

Approximately 100 individuals of *P. sylvatica* were counted by Lysák (2000) close to Hodíškovský pond. Nowadays, twenty years ago, the locality is a protected area and is regularly mowed. The population partly decreased, but active management has led to preservation of the population, which remain probably as most numerous in the whole region with approximately 50 pieces counted recently on the locality. Similarly, about 50 individuals were counted at the Rendlíčkový pond (close to Břeží nad Oslavou) in 2002 (F. Lysák, personal observation). The revision of the occurrence was carried out later by A. Rešlová in 2012 (PLADIAS 2018). Close to Nový pond to the west (close to village Zadní Zhořec), new finding was recorded in 2004 (F. Lysák, personal observation). There were about 50 individuals counted in 2004. Later revision of the occurrence made by L. Čech did not mention the numbers of individuals (PLADIAS 2018).

Occurrence of *Pedicularis palustris*

Rarer of both studied species was documented from the region from two localities - Bohdalovský pond and Těšíkův pond (PLADIAS 2018). Twenty individuals were counted in 2001 on the latter locality (F. Lysák, personal observation). Both of the population extinct due to the successional vegetation changes after management abandonment. At the Těšíkův pond, the last mowing was observed in 2001 and the species continuously disappeared in subsequent years. In 2016, mowing has been restored to recover the population, unfortunately without success. The species did not appear anymore through optimal environmental conditions and management, probably because of absence of viable seeds in the soil.

Causes of *Pedicularis* populations decline

The main cause of declining and disappearing populations of *Pedicularis sylvatica* is the eutrophication caused by nutrient input from fertilizing agriculture land in the surrounding and absence of suitable mowing management. Higher nutrient availability prefers expansion of strongly competitive nitrophilous species at the expense of more and more endangered poorly competitive species of native wetland habitats. The survey showed that even in mowed meadows the numbers of individuals decreased. Dense vegetation dominating by grasses prevents germination and rooting of seedlings in patches with absence of disturbances. The other reason can be connected with climate changes, which are now more unfavourable for species dependent on regular precipitation and water saturation. Paradoxically, period of drought during summer has partly also a positive effect at Znětínský pond, by cracking the surface of the dense grassland. Regular mowing is not enough, we need also to set up a management that would include needs with respect to phenology of the target species, with combination of surface disruptions. A good example could be grazing. This problem also applies to other plants in the region (*Dactylorhiza majalis*, *Parnassia palustris*, *Taraxacum nordstedtii*). For *Pedicularis palustris*, it is hard to find recommendations. It looks that the seed bank of the species is exhausted, and historical findings were only residual of the dying populations. The species has disappeared and suitable habitats are no longer there.

CONCLUSION

Despite the huge effort put into nature conservation in the Czech Republic, financial covering and/or qualifying practice of the nature conservation management is still insufficient and we still see a continuous biodiversity decline and degradation of natural habitats. Monitoring of populations of two threatened species, *Pedicularis palustris* and *P. sylvatica*, in study region confirms the need for more effective local nature conservation. One of the studied species, *P. sylvatica*, declined in number of populations to a third during twenty years with decreasing in population sizes in the persistent localities. The second species, *P. palustris*, extinct completely in the whole region. Reducing population abundances also in case of well-managed localities indicates a change in abiotic factors due to climate change. Whereas the human-made negative influences on natural habitats, are possible to reduce by suitable management. Preventive measures in the form of restricting direct fertilization and liming of wet meadows are crucial. Whereas, unfortunately, the main source of eutrophication, nutrients leaching from the surrounding agricultural landscape, are difficult to simple limit. Continual long-term pasture

and mowing in terms corresponding to species phenology with small disturbances important for germination of the seedlings, remain as the most suitable management possibilities.

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