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PEDICULARIS OEDERI (SCROPHULARIACEAE) IN THE CHORNOHORA MTS (UKRAINIAN CARPATHIANS): DISTRIBUTION, BIOLOGY, ECOLOGY AND THREAT

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Abstract: Ten localities of *Pedicularis oederi* Vahl from the Chornohora Mts (Ukrainian Carpathians) are described and mapped. They represent the only remaining metapopulation of the species in the region. The life history and population parameters of the species are depicted, and habitat characteristics are given. Grazing is regarded as the main threat to the species. It should be considered endangered. The most effective way to protect *P. oederi* and a number of other endangered species is to incorporate the Brebeneskul Mt. massif into the core zones of two reserves which share that area.

Key words: *Pedicularis oederi*, population, life history, endangered species, conservation, Carpathians

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INTRODUCTION

Information on the current situation of threatened and rare plant species in the Ukrainian Carpathians is obviously insufficient (Kobiv 1997), hindering proper designation of their status and implementation of effective conservation measures.

This article is intended to help fill that gap in regard to one species – *Pedicularis oederi* Vahl (= *P. versicolor* Wahlenb.). The aim of the study was to obtain primary data concerning its present distribution, ecological requirements, population parameters, recruitment, and threat factors in the highest part of the Ukrainian Carpathians – the Chornohora Mts. Another goal was to provide a basis for further monitoring in order to prevent the extinction of the species.

GENERAL DISTRIBUTION

Pedicularis oederi is a typical arctic-alpine species with a disjunctive area. The largest, amphiarctic part of its area covers the whole tundra zone of arctic and subarctic Asia, extending somewhat into Northern Europe and North America (Meusel *et al*. 1978). It also penetrates southward along the Ural Mts. In northwestern Europe the species occurs in Fennoscandia. Another part of the area is restricted to high-mountain regions of Asia and Europe. Most probably *P. oederi* is of North Asian origin, and the concentration of some closely related species in that region backs up that suggestion (Kulczyński 1927; Pawłowska 1977). In Central and Eastern Europe it may be regarded as a relict of the glacial age (Pawłowska 1977).

In the temperate zone of Europe *P. oederi* is restricted to oligothermic conditions, mostly in high-mountain regions. It occurs in the Alps within the altitudinal range of 1600–2400 m (Hegi 1918; Meusel *et al*. 1978), in the Carpathians within 1000–2550 m (Jasiewicz 1963; Holub & Kmeťová 1997), and in the Balkans within 2000–2800 m (Peev 1995). European localities are isolated. For example, in the Carpathians the species is scattered in the following mountain ranges: the Tatra, Chocz (Jasiewicz 1963; Holub & Kmeťová 1997), Rodna, Bistrits, Ciucash, Fagarash, Iezer-Papusha (Pauca & Nyárády 1960), Marmarosh (Stoyko & Tasenkievich 1996) and Chornohora Mts (Kotov 1960).

DISTRIBUTION IN UKRAINE

In Ukraine, *P. oederi* occurs mainly in the Chornohora Mts. Zapałowicz (1889) was the first to report stations of the species in the vicinity of Brebeneskul Mt., giving their location and elevation. Later on, Raciborski (1911) mentioned that the species occurs near the summit of Pip Ivan Mt. The latter locality was also confirmed by Slobodian (unpublished) and by some herbarium specimens. Domin (1929) described the location of one more station on Petros Mt. Malinovskiy (1980) reported a station on Hoverla Mt.

Recently *Pedicularis oederi* was reported from the Marmarosh massif (Stoyko & Tasenkievich 1996).

METHODS

The results presented were obtained during field research in 1996–1998. We used meander search (Given 1994), looking for species localities in areas where *Pedicularis oederi* had been reported by the above-mentioned authors or confirmed by herbarium specimens.

The description of the life history, especially its beginnings, is based on observations of marked individuals *in situ* (Rabotnov 1950; Harper 1977). Thirty plants belonging to different age groups were used for that purpose. Examination of subterranean organs also provided much information on the life history (Serebryakov 1952; Rabotnov 1960; Harper 1977; Bell & Tomlinson 1980), because it reveals year-by-year rhizomatous increments and traces from former stems. As the species is not numerous, we could dig up only a limited number of individuals (5–15 for each age group) to study their subterranean organs, take photographs, weigh and herbarize them. Accordingly, 'typical' individuals were collected only from the most numerous localities: I, II, IX and X. All the measurements presented in Table 3 were obtained from live plants. All the weight data are given as dry values.

Species abundance in Table 1 is presented according to Braun-Blanquet's (1951) scale.

The density and age structure of populations were estimated on transects for larger localities or on square plots for smaller ones (Rabotnov 1964; Harper 1977; Given 1994).

The overall calcium content in the soil was evaluated by means of atomic absorption spectroscopy using a Selmi C-115 M1 apparatus. The samples were pretreated consecutively with HF and a 3:1 mixture of HCl and HNO_3 (Geletiuk & Zolotariova 1978).

Nomenclature for vascular plants is according to Mirek *et al.* (1995), and Corley *et al.* (1981) for bryophytes.

RESULTS

LIFE HISTORY AND PHENOLOGICAL DEVELOPMENT

Leaves begin to develop in the middle of June, about a week after snow melt. Flowering usually takes place from July 1 to 15, and dissemination in the first decade of August. Fertile shoots die off in August but remain erect. Development of leaves in vegetative rosettes slows down but they continue to function till September.

First-year plants (Fig. 1). Seedlings appear in June. They have ovate or elliptic shiny cotyledons about 5 × 3 mm in size. Later the first leaves develop, having only 8–10 rows of segments with even margins. A primary root grows vigorously at the same time, reaching about 2 mm in diameter till the end of June. It is much thicker than the hypocotyl. Branch roots appear as well.

In August the young plants have a rosette of 3–4 leaves, which are 3.5–7.0 cm long. Their laminae resemble those of adult plants – the segments have distinct incisions. A rhizome begins to develop then; it is about as thick as the proximal part of the main root (*ca* 3 mm).

Second-year individuals have a much better developed rosettous shoot. A rosette consists of 4–7 leaves. They are 6–14 cm long. Lateral buds appear on the rhizome in the middle of summer. They may initiate branching later. The direction of rhizomatous growth may be either orthotropic or plagiotropic. The rhizome reaches 4.0–5.5 mm in diameter. It grows monopodially at this stage; the annual increment is 5–12 mm during that year. The main root still dominates, though branch roots grow intensively.

Third-year plants have one flowering shoot, which develops from the terminal bud. One to six (2–4 typically) vegetative rosettous shoots usually form at the base of the stem as well. They origin-

Table 1. Floristic composition of vascular plants in examined localities (I–X) of *Pedicularis oederi* Vahl in the Chornohora Mts.

Locality number	I	II	III	IV	V	VI	VII	VIII	IX	X
Pedicularis oederi	1	1	+	+	+	+	+	+	+	+
Alchemilla obtusa	.	+	.	.	.	.	.	.	.	.
Allium sibiricum	+	1	.	.	.	1	.	.	.	.
Anthoxanthum alpinum	1	1	.	.	.	.	.	.	.	+
Caltha palustris subsp. *laeta*	+	1	.	.	.	2	.	.	.	.
Cardamine pratensis	+	.	.	+	.	.	.	+	.	.
Carex flava	2	1	.	.	.	.	.	.	.	.
Carex nigra	2	1	+	.	.	.	.	.	.	.
Carex rostrata	2	.	.	.	.	.	.	.	.	.
Carex sempervirens	.	+	.	.	2	.	1	1	2	2
Cerastium fontanum	.	.	.	+	.	.	.	.	.	.
Dactylorhiza cordigera	+	.	.	.	.	.	.	.	.	.
Deschampsia caespitosa	1	3	2	1	.	1	2	.	3	3
Equisetum palustre	2	1	.	.	.	.	.	.	.	.
Eriophorum vaginatum	1	1	.	.	.	.	.	.	.	.
Festuca picta	+	.	.	.	.	.	.	.	+	.
Juncus trifidus	.	.	.	.	.	.	.	.	+	.
Juncus triglumis	+	.	.	.	.	.	.	+	.	.
Leontodon croceus	+	+	.	.	1	.	+	+	+	.
Ligusticum mutellina	2	1	.	1	2	.	1	1	+	+
Luzula sudetica	+	+	.	.	.	.	.	.	.	.
Parnassia palustris	+	+	.	+	.	+	.	.	.	.
Polygonum bistorta	.	.	.	+	.	.	.	.	.	.
Polygonum viviparum	+	.	.	.	.	.	.	.	.	+
Primula minima	.	.	.	.	+	.	.	.	.	.
Ranunculus strigulosus	+	1	1	.	.	.	1	1	+	.
Salix bicolor	+	.	.	.	.	.	.	.	.	.
Sesleria bielzii	.	.	.	.	1	.	.	.	+	+
Soldanella hungarica	.	+	.	.	.	.	.	.	.	+
Swertia punctata	+	1	1	.	.	1	+	1	.	.
Vaccinium uliginosum	.	.	.	1	.	.	.	.	.	.
Viola biflora	.	.	+	.	.	+	.	.	.	+

ate from the previous year's lateral buds. Such shoots are smaller than in second-year plants. Commonly they have only 2–4 leaves, which are 5–10 cm long. The rhizome is 9–14 mm in diameter; its annual length increment is 7–16 mm. A number (5–10) of lateral buds usually form on it. Fleshy branch roots exceed the main one, which becomes hardly distinguishable now. They may be horizontal, descending or ascending, and also have a contractile function. Their diameter may reach 9 mm.

Fourth-year plants have up to four (mostly 2) growth axes. Each such module bears a flowering shoot, which develops from a previous-year lat-

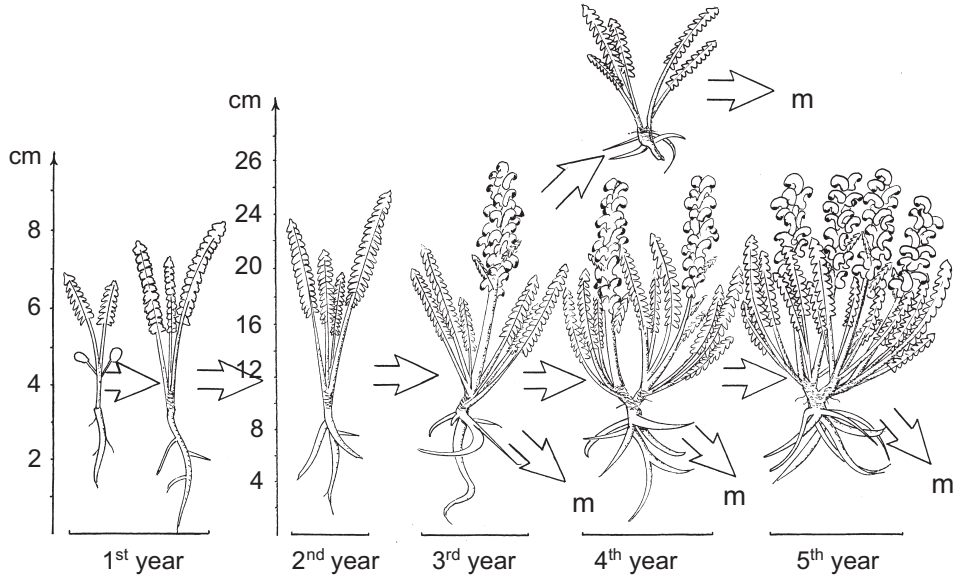

Fig.1. Life history of *Pedicularis oederi* Vahl. m – death of individuals.

eral vegetative shoot. Thus each monocarpic growth axis is dicyclic (Serebriakov 1952), that is, it has to undergo a one-year vegetative stage before flowering. The length of current rhizomatous increments is about the same as in the previous year. A distinct mark from the last-year flower stem remains on the rhizome. Sometimes a small number of poorly developed, thin adventitious roots form on the proximal part of the rhizome.

The vast majority of individuals that have reached the fertile period die off after their first or second dissemination. Thus, the full-range life span typically lasts 3–4 years. Some plants undergo one more (third) flowering period, however, before they die off. They have 4–5 flower stems and rhizomes with second-order branches.

A small percentage of individuals pass a one-year barren post-fertile (senile) period at the end of their life cycle. They have only 1–3 vegetative shoots with a small number of leaves (2–3) in each rosette. The above-ground shoots resemble those of the 2nd-year pre-flowering plants, but their subterranean organs differ significantly. Post-flowering individuals have thick last-year parts of the rhizome and very thin (*ca* 3.5 mm in diameter) current-year increments. Their roots present only the remains of the former root system, most of which has become rotten by that stage. All the post-flowering individuals we registered belonged to the 4th-year group, that is, they had undergone only one flowering period.

The vegetative mobility of *P. oederi* is not high. The length of the rhizome in adult plants never exceeds 5.5 cm. No vegetative reproduction has been noted. Because almost no adventitious roots are formed on the rhizome, they do not play a significant role in plant nutrition. Therefore, any partition of the rhizome or its branch would lead to the death of the fragment. The vast majority of individuals are represented by a single module. Only the oldest flowering ones have several modules. They are closely aggregated because (1) the rate of vegetative spread is low and (2) the growth of rhizomatous branches is almost parallel.

The life history course is strictly determined – an individual develops steadily from seed to death through the fertile stage without any rejuvenation. No temporary cessation of fertile function has ever been noted. Individuals that have lost their flowering ability are subject to death, though they

may exist in a stunted condition for one more growing season (senile plants). *Pedicularis oederi* is a short-lived perennial and its life strategy is much the same as in annual and biennial species. It is directed toward developing flowering shoots and producing seeds once or a few times. Neither expansion by means of vegetative spread nor long life span are intrinsic to this species.

The life history of *P. oederi* resembles that of *P. hacquetii* Graf described by Piekoś-Mirkowa and Łobarzewska (1990). Though both species belong to the same genus and their life cycles are very similar, *P. oederi* has some peculiarities: (1) its individuals may produce more than one module, that is, rhizomatous branching occurs; (2) plants may have more than one flower stem; (3) the fertile stage may cover 3 years; (4) the life span may last up to 5 years; (5) some individuals undergo a post-fertile stage before they die off.

LOCALITIES IN THE CHORNOHORA MTS

All the localities of *P. oederi* we found are in the massif of Brebeneskul Mt. (Fig. 2), and are hardly more than 1.5 km apart. We regard all these individuals as a single metapopulation comprised of separate subpopulations differing in their area, numbers (Table 2) and age structure (Fig. 3), as well as in their phytocoenotic and ecological conditions.

Locality I is the most numerous. It lies in the lower cirque of the Kizi Ulohy valley between Brebeneskul and Munchel Mts on a peat bog dominated by *Carex rostrata* Stokes and the mosses *Sphagnum riparium* Angstr., *Campylium stellatum* (Hedw.) J. Lange & C. Jens. and *Calliergon stramineum* (Brid.) Kindb.

Locality II is not far from the first, at the foot of Munchel Mt. It is less marshy, though mostly hygrophytous species occur at the habitat, such as *Allium sibiricum* L., *Caltha palustris* L. subsp. *laeta* (Schott, Nyman & Kotschy) Hegi, *Carex flava* L., *Equisetum palustre* L., *Eriophorum vaginatum* L., *Luzula sudetica* (Willd.) DC., *Swertia punctata* Baumg. and *Ranunculus strigulosus* Schur (Table 1).

Localities III–VIII are associated with the springs of small streams on different slopes of Brebeneskul Mt. They have very few individuals, with 8 to 45 adult (> 1-year-old) plants. No flowering individuals were found in Localities VI and VIII in 1997. *Swertia punctata*, *Ligusticum mutellina* (L.) Crantz, *Leontodon croceus* Haenke and *Ranunculus strigulosus* are most common in these habitats. Mosses, especially *Ctenidium molluscum* (Hedw.) Mitt. and *Philonotis caespitosa* Jur., are also abundant there.

Localities IX–X lie on the uppermost part of the mountain ridge. They are much more mesophytic, the driest compared to the previous stations. These localities are dominated by *Carex sempervirens* Vill. and *Deschampsia caespitosa*

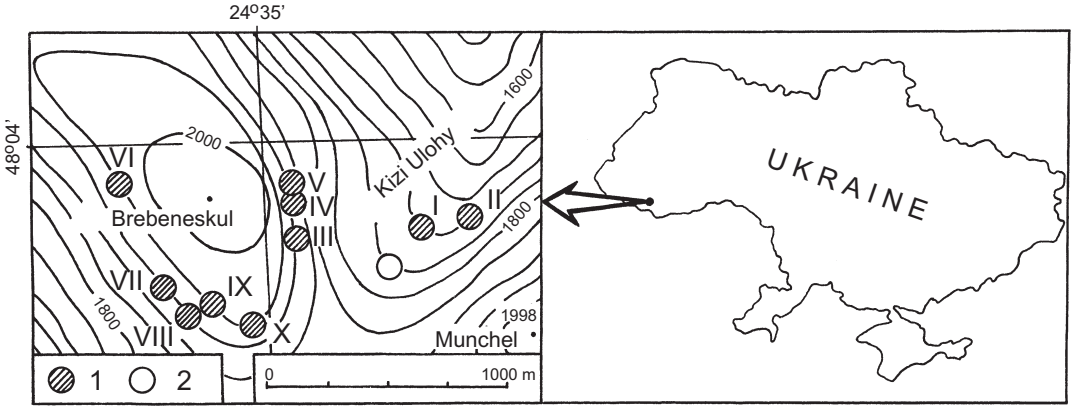

Fig. 2. Distribution of *Pedicularis oederi* Vahl in the Chornohora Mts. I–X – locality numbers; 1 – confirmed locality; 2 – extinct locality.

Table 2. Population parameters of *Pedicularis oederi* Vahl in different localities in 1997.

Locality	Characteristics of localities	Altitude m	Aspect	Area m^2	Number of adult vegetative individuals	Number of flowering individuals (July 12)	Number of seed-bearing individuals (August 2)	Average number of adult individuals per sq. m	Seedlings/adult individuals ratio
I	peat bog	1720	bottom of cirque	80	400–450	105	62	6.6	2.5
II	wet meadow	1720	NE	25	100–110	32	26	5.5	1.6
III	near spring	1915	E	5	31	6	6	7.4	2.8
IV	near spring	1925	E	5	38	7	5	9.0	3.1
V	near spring	1920	SE	4	26	8	5	8.5	2.5
VI	near spring	1950	W	5	10	–	–	2.0	2.8
VII	near spring	1935	SSW	10	16	3	2	1.6	3.2
VIII	near spring	1940	S	5	8	–	–	1.6	2.5
XI	mesophytic grassland	1955	S	250	120–150	50	~30	0.5	1.4
X	mesophytic grassland	1955	SSE	300	150–200	65	~40	0.6	1.5

Table 3. Parameters of individuals of *Pedicularis oederi* Vahl in wet (I) and mesophytic (X) localities in 1997.

Locality	2^{nd}-year vegetative individuals			3^{rd}-year flowering individuals						
	Sample number	Length of leaves cm	Dry weight g	Sample number	Height cm	Dry weight g	Number of flowers per stem	Number of capsules per stem	Number of seeds per capsule	Seed productivity per stem
I	15	9.6±0.6	0.38±0.2	12	9.6±0.4	1.25±0.13	10.7±0.5	9.4±0.5	6.1±0.2	57.3
X	15	12.3±0.7	0.48±0.2	8	12.1±0.5	0.78±0.08	14.2±0.6	13.3±0.7	7.0±0.3	83.3

(L.) P. Beauv. Their area is the largest but the density of *P. oederi* is the lowest (Table 2).

POPULATION PARAMETERS IN THE EXAMINED LOCALITIES

The age structure in most localities investigated represents a pyramid (Fig. 3). The percentage of each year's age group is higher than the older one. For example, typically there are more 2nd-year vegetative individuals than 3rd-year flowering ones. This is quite expected because of the extinction of some individuals at each stage, each of which lasts a year. Theoretically there can deviations from this pattern in some small populations, because fertile individuals may be drop out of the population from year to year and consequently no seedlings will appear the next year.

Seedlings prevailed over adult individuals in all the examined localities. The seedling/adult ratio varied from 1.4 to 3.2 (Table 2). It was the lowest in mesophytic grassland Localities IX–X, indicating that the dense tussock impedes the establishment of young plants there. This also applies to pre-fertile vegetative individuals, and is the main cause of the low density of *P. oederi* in these habitats.

In contrast, the high density of the species observed in some wet localities (I, III–V) can be explained by the presence of numerous patches of barren soil and moss that are favorable for recruitment of *P. oederi*.

The individual parameters of plants differ depending on their habitat. Table 3 presents some numeric data obtained from two stations with contrasting conditions – peat bog Locality I vs. mesophytic grassland Locality X. Individuals from the latter station are higher (because they have to compete among the dense tussock) and bear more flowers or seed capsules per stem. Consequently their seed productivity is higher; this may be adaptive in conditions of poor establishment of seedlings. Despite these physical features, the flowering individuals from the wet Locality I are significantly heavier.

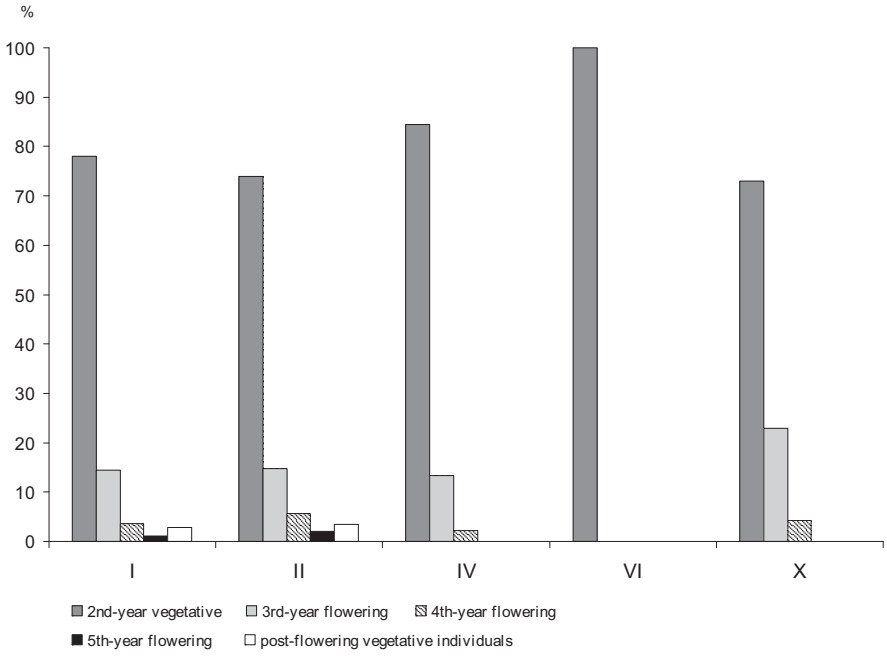

Fig. 3. Population structure of *Pedicularis oederi* Vahl in Localities I, II, IV, VI and X (adult plants only).

The oldest (5th-year) flowering individuals and post-flowering ones were found only in the lowest localities (I, II), meaning that the life span is longest there.

COENOTIC AND ECOLOGICAL CONDITIONS

It is known from the literature that *P. oederi* in the Polish, Slovakian and Romanian Carpathians is most common in mesophytic grassland and rock communities. *P. oederi* is regarded as a character species for the *Seslerion tatrae* alliance (Pauca & Nyárády 1960; Jasiewicz 1963; Pawłowski 1977; Matuszkiewicz 1981; Holub & Kmeťová 1997). Wet habitats are considered to be less typical for the species. Some authors (Jasiewicz 1963; Holub & Kmeťová 1997) also note that *P. oederi* is calciphilous.

It is different in the Chornohora Mts. Eight (I–VIII) out of ten examined localities are wet habitats. Analysis of calcium content in the soil revealed only traces of that element (≤ 2 μg/g) in Locality I and 36 μg/g in Locality VII. The soil in all the tested localities was markedly acidic, with pH (H_20) values of 4.7–5.3.

Locality I represents the association *Caricetum rostratae* (alliance *Magnocaricion*). The rest of the wet localities are associated with running water. Most of them (III–VIII) occur near springs and belong to the class *Montio-Cardaminetalia*. Only the mesophytic grassland Localities IX–X correspond to *Caricetum sempervirentis* (alliance *Seslerion tatrae*).

The species most often occurring in the close vicinity of *Pedicularis oederi* are *Ligusticum mutellina, Swertia punctata* and *Carex sempervirens* (Table 1).

CONSERVATION CONSIDERATIONS

The main negative factor affecting all the alpine localities (III–X) is grazing. It still occurs here from time to time, though the area is included in the buffer zone of the Carpathian Biosphere Reserve (NE part of the ridge adjacent to Brebeneskul Mt.) and the Carpathian National Nature Park (SW part of the ridge). We noticed that grazing and associated trampling often damage the stems of *Pedicularis oederi*. This undermines normal reproduction of the species.

Even in undisturbed localities there is a great difference between the numbers of flowering stems in July and the numbers of well-developed seed-bearing ones in August (Table 2). A significant part of the shoots die off after flowering. For example, in Localities I, V, IX and X in 1997, seeds developed only on about 60% of the stems.

The low outcome of seed-bearing stems may pose a significant threat to low-numbered wet alpine localities (III–VIII) situated near springs, because it affects the sustainability of the populations. The complete lack of seed outcome in some localities in certain years may have the following causes: (1) the absence of flowering individuals; (2) damage to the shoots from grazing or trampling; and (3) natural stunting of the shoots after flowering. When no dissemination occurs for two consecutive years in a locality, the subpopulation is prone to extinction if the seeds lose their viability within a year and only 3rd-year individuals germinate.

At present *P. oederi* occurs in only six wet spring-related localities (III–VIII), though many more such places are scattered throughout the area. These habitats might have been inhabited by the species earlier. Though potentially they may be reinvaded, the species seems to be vanishing gradually in the alpine zone. At the end of the 19th century, Zapałowicz (1889) pointed out that *P. oederi* was 'rather abundant' on the ridge near Brebeneskul Mt., but that is far from the case now. It is quite evident that the number of individuals has declined. *Pedicularis oederi* has become extinct at the Zapałowicz locality noted on the peat bog in the upper cirque of Kizi Ulohy.

The most dramatic losses have occurred at other stations situated farther from Brebeneskul Mt. We failed to find *P. oederi* on Pip Ivan, Petros and Hoverla Mts where it was reported by Raciborski (1911), Domin (1929), Malinovskiy (1980) and Slobodian (unpublished), though the location of the stations was stated quite clearly. Most probably the species has become extinct there. The

sites indicated by the above authors are mesophytic grassland communities of the alliance *Seslerion tatrae*. They have been subjected to severe grazing, perhaps the main cause of the species' extinction, for a long period of time.

Another cause of the decline of *P. oederi* in the Chornohora Mts seems to be natural extinction. All the localities – both actual and extinct – are in the uppermost parts of the mountain range. Most probably they represent only the remains of a much larger common area which included all of them in the previous, more oligothermic period.

Present conditions in the Chornohora Mts are not favorable for *P. oederi*. The poor sustainability of its populations can be explained by low seed yield. For example, only about 15,000 seeds were produced in all the examined localities in 1997. The overall numbers of seed-bearing individuals was about 170, which is critically low. The situation can be improved by complete cessation of grazing in the region. This will prevent damage to the shoots.

Pedicularis oederi is protected in some countries; it is regarded as vulnerable in Slovakia (Marhold & Hindák 1998) and rare in Bulgaria (Dakov 1984). It is included in the 'Red Data Book of Ukraine' (Stoyko & Tasenkievich 1996). According to IUCN Red List categories (1994) the status of *P. oederi* in Ukraine should be classified as endangered (EN) because in the Chornohora Mts, which is considered the main region of the species' distribution in Ukraine, it is represented by a single sparse population that is evidently declining. All the remaining localities are situated in the close vicinity of Brebeneskul Mt. The most effective way to promote the species' survival is to incorporate the adjacent massif into the core zones of the Carpathian Biosphere Reserve and the Carpathian National Nature Park, which presently share that area. This should stop uncontrolled grazing, which affects the species. It is all the more reasonable because such rare and threatened species as *Gentiana lutea* L., *Ranunculus thora* L., *Callianthemum coriandrifolium* Rchb., *Saxifraga aizoides* L., *Saussurea alpina* (L.) DC. and *Dryas octopetala* L. occur here as well (Kobiv & Nesteruk 1996).

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