

***PULSATILLA VERNALIS* (RANUNCULACEAE) IN THE POLISH LOWLANDS: CURRENT POPULATION RESOURCES OF A DECLINING SPECIES**

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Abstract. We report the results of an inventory of localities of *Pulsatilla vernalis* (L.) Mill carried out after 2000 in the lowland part of its distribution range in Poland, as a contribution to a timely revision of the current population resources of this species, which has been in drastic decline in recent dates. The species was previously reported from 189 10×10 km squares of the Polish mapping grid (ATPOL), based on all then-known records. During our field work we confirmed its presence in 15 ATPOL squares, with a total of 26 persisting populations. Further research will no doubt add some data, especially in N Poland, but is not likely to change the overall statistics much. Most of the populations we observed were very small and lacked young plants despite regular flowering and fruiting. The majority of the populations were in the Bory Tucholskie region, the only remaining area where the species is relatively well represented. Outside this area only three very isolated populations were confirmed in S Poland (the biggest and demographically most dynamic one is in the vicinity of Bełchatów). Based on these results we suggest raising threat category of *P. vernalis* in Poland from VU to EN, and further protection measures: (i) continuous inventorying of populations based on scientific studies, as well as measures involving land owners/users, tourists and others; (ii) selection of populations for regular monitoring, and (iii) selection of the most valuable populations for active site protection to prevent habitat destruction.

Key words: declining species, legal protection, Poland, rare plants, relict populations, threatened plants

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INTRODUCTION

Pulsatilla vernalis (L.) Mill. is strictly protected in Poland but its populations have been in drastic decline in recent decades. It is now one of the rarest plants in the flora of Poland.

Pulsatilla vernalis occurs only in Europe; it represents a separate range type within the Central European geographical element, having two distinct distribution centers: a mountain and a lowland one (Pawłowski 1928; Pawłowska 1977). The mountain part of the range comprises isolated areas of the European Alpine System, such as the Pyrenees, Central Massif, Alps, Carpathians, Balkan mountains and the southern part of the Scandinavian chain. The lowland distribution range is in Central Europe and southern Fennoscandia (Sweden, Finland and Russian Karelia) (Jalas & Suominen 1989; Ronikier 2005). In most

regions of the mountain range part, *P. vernalis* is a frequent species and even a common one, for example in the subalpine and alpine zone of the Alps and the Scandinavian chain (M. Ronikier, pers. obs.). In Poland as well, even though the mountain range area is represented by only a few small populations in the High Tatra mountains, these populations seem to be ecologically and demographically stable (Mirek *et al.* 2008; M. Ronikier, unpubl. data). The situation is the reverse in all parts of the lowland distribution center, where the species is either extinct or ranked in a high threat category. Floristic accounts and the available herbarium records indicate that lowland populations were still relatively frequent at the turn of 19th/20th centuries. A substantial decline of its resources was noted through the rest of the

20th century. In Austria it is extinct in lowlands (Adler *et al.* 1994), although it is well represented in herbarium material from the early 20th century (M. Ronikier, unpubl. data). In Germany only a few lowland populations remain in the Bayern region (Scheuerer 1996), while more to the north, in Sachsen, the last plants were observed in 1922 (Hempel 1976); accordingly, the species is considered critically endangered on the country scale (Korneck *et al.* 1996). It has the same status in the Czech Republic (Čeřovský 1999). The most numerous lowland populations were reported to persist in the Russian Karelia (Simačev 1978, 2000) and in Scandinavia, but at least in Scandinavia a serious decline of populations has been noted in recent years (Wind 1993; Åström & Stridh 2003). The easternmost locality reported from Belarus is considered extinct (Parfenov *et al.* 1987). The condition of its populations is similar in the Polish lowlands (Wójtowicz 2001; Fig. 2). This suggests that the primary center of its distribution is in the mountains, while in the lowlands the populations are relict (Pawłowski 1928; Szafer 1977). Such a scenario finds support in the phylogeographic pattern found in extant populations (Ronikier *et al.* 2008).

Pulsatilla vernalis (Fig. 1) was first reported from Poland in the 19th century (e.g., Rostafiński 1872). According to published historical information and herbarium data, as late as the turn of the 19th/20th centuries it occurred at dispersed yet numerous localities from Silesia northwards to Pomerania (e.g., Ascherson & Graebner 1898–1899; Schube 1904). Historically the regional populations marked the eastern limit of the species, running longitudinally through the middle part of present-day Poland. All hitherto known localities served as the basis for the species distribution map published in the *Distribution Atlas of Vascular Plants in Poland* (Zajac & Zajac 2001). Most of these records were noted before World War II and should be regarded as historical unless confirmed, as Wójtowicz (2001) stated. In many cases, field searches done for the purpose of evaluating the species for regional red lists and books in the lowland distribution areas of *Pulsatilla vernalis* revealed that regional populations had become extinct.

According to the threat estimation criteria based on IUCN guidelines, *Pulsatilla vernalis* has been classified as a vulnerable species (VU category; Wójtowicz 2001). This category was maintained in a recent edition of the red list of plants in Poland (Zarzycki & Szelağ 2006), even though regional editions gave it a higher threat status or considered it 'regionally extinct' (Parusel *et al.* 1996; Nowak *et al.* 2003). Currently the largest concentration of *P. vernalis* populations is in the Bory Tucholskie region in Western Pomerania (Wójtowicz 2001), where it was also reported in several earlier publications (e.g., Ceynowa 1971; Boiński & Gugnacka-Fiedor 1977).

Field revision of the *Pulsatilla vernalis* localities reported in the last two centuries is a difficult and sometimes impossible task, but it has to be attempted in order to arrange monitoring of existing population resources and to draw up a conservation plan for it in Poland. Here we report the results of the first comprehensive stage of work aimed at a detailed analysis of existing population resources of *P. vernalis* in Poland and the distribution of its extant localities. The work involves verifying previously published data in the field and our own field research. In the field we verified the data from some of the available records, estimating the size of existing populations, their demographic tendencies and potential threats. Our inventory is a contribution to the comprehensive chorological studies that are needed to determine the actual distribution of the species in Poland and to analyze changes and conservation prospects.

MATERIALS AND METHODS

The field inventory of populations was done in 2000–2001 and 2006–2008. The area and potential localities for verification were selected based on literature data and our floristic research. As a guideline, in the first stage of this revision we did not search in areas where the species was either considered extinct based on recent literature data or in areas beyond its known distribution range.

The description of localities is based on the administrative division of Poland and on Forest Service maps of state forests. We used the borders of forestry districts and state forest divisions to describe site locations in the Bory Tucholskie forest. The higher-level regionalization

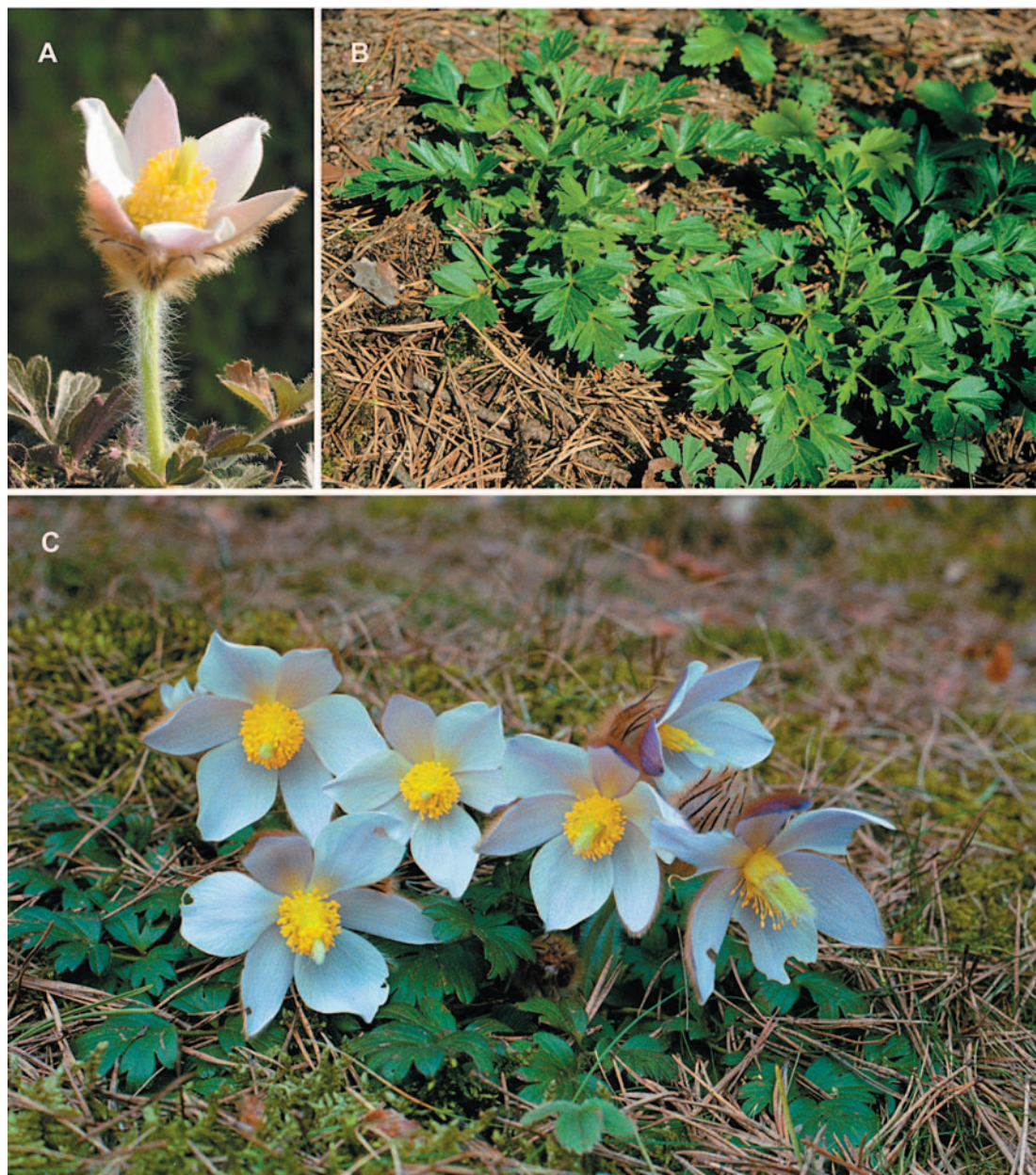


Fig. 1. *Pulsatilla vernalis* (L.) Mill. in lowland localities. A – flowering plant shoot in Rogowiec near Bełchatów (population 24), 2 Apr. 2007. B – vegetative plants shoots in Sielanka (population 23), 2000. C – flowering plant shoot in Bocheniec (population 26), 12 Apr. 2008. Photo: A & C – A. Grzyl, B – M. Ronikier.

of Poland follows Kondracki (2000). Exact locations in the field were recorded with a GPS system. Situation sketches and photographic documentation were made on site, and the basic habitat characteristics were noted. At

each site the population size was estimated by counting individual shoots. The current distribution of localities is presented on a map using ATPOL grid for mapping the flora of Poland (Zając 1978; Fig. 2).

Table 1. Localities of *Pulsatilla vernalis* (L.) Mill. in the Polish lowlands discovered or confirmed after 2000 during the present study. Sites within State Forests are identified by forestry district (For., and forest section number) and forest division (For. div.). Classes of estimated population size: A – 1–10, B – 11–50, C – 51–100, D >100. Plant groups growing close to each other are treated as a single locality.

No.	ATPOL square	Locality	Geographical coordinates	Pop. size	Habitat
1	CB46	For. Juńcza, c. 76a For. div. Czersk	N: 53°51'53" E: 17°58'08"	A	Edge of pine forest at communal road
2	CB48	For. Baby, c. 200a For. div. Kaliska	N: 53°49'40" E: 18°17'37"	A	Roadside slope of communal road by pine forest
3	CB55	For. Legbąd, c. 41b For. div. Woziwoda	N: 53°42'01" E: 17°56'14"	B	Edge of pine forest at forest district line
4	CB56	For. Ustronie, c. 19 For. div. Woziwoda	N: 53°46'22" E: 18°01'46"	A	Edge of pine forest at forest district line
5	CB56	For. Ustronie, c. 44b For. div. Woziwoda	N: 53°45'29" E: 18°01'18"	A	Edge of pine forest at forest district line
		For. Ustronie, c. 45g For. div. Woziwoda	N: 53°45'28" E: 18°01'08"	A	Edge of pine forest at communal road
6	CB56	For. Legbąd, c. 55a For. div. Woziwoda	N: 53°42'38" E: 17°58'51"	B	Edge of pine forest at forest district line
7	CB56	For. Legbąd, c. 77b For. div. Woziwoda	N: 53°42'10" E: 17°59'30"	A	Edge of pine forest at forest district line
8	CB57	For. Lipowa, c. 270 For. div. Woziwoda	N: 53°43'15" E: 18°06'60"	A	Edge of pine forest in vicinity of railway
9	CB65	For. Legbąd, c. 29c For. div. Woziwoda	N: 53°41'45" E: 17°54'11"	A	120-year pine forest stand (seed bank forest)
10	CB66	For. Biała, c.: 153b For. div. Woziwoda	N: 53°40'30" E: 17°58'53"	C	Edge of pine forest at forest district line
		c. 154d	N: 53°40'32" E: 17°58'49"		
		c. 175d	N: 53°40'05" E: 17°59'41"		
		c. 176b	N: 53°40'10" E: 17°59'12"		
11	CB66	For. Kiełpiński Most, c. 66 For. div. Tuchola	N: 53°38'09" E: 17°58'10" N: 53°39'20" E: 17°59'20"	B A	Edge of pine forest at forest road Edge of pine forest at forest road
12	CB67	For. Lisiny, c. 97 For. div. Trzebciny	N: 53°39'35" E: 18°08'01"	A	Edge of pine forest
13	CB67	For. Lisiny, c. 146 For. div. Trzebciny	N: 53°40'05" E: 18°12'23"	C	Edge of pine forest and railway embankment
14	CB67	For. Zimne Zdroje, c. 113 For. div. Trzebciny	N: 53°40'50" E: 18°12'46"	A	Edge of pine forest at forest road
15	CB68	For. Osie, c. 310 For. div. Osie	N: 53°40'17" E: 18°19'45"	A	Edge of pine forest at forest district line
16	CB68	For. Stara Rzeka, c. 115 For. div. Osie	N: 53°38'02" E: 18°21'00"	C	Edge of pine forest at forest road
17	CB68	For. Stara Rzeka, c. 74, 75 For. div. Osie	N: 53°38'48" E: 18°21'01"	C	Roadside slope of forest road
18	CB76	For. Rudzki Most, c. 132 For. div. Tuchola	N: 53°33'03" E: 17°56'45"	A	Edge of pine forest at forest road

Table 1. Continued.

No.	ATPOL square	Locality	Geographical coordinates	Pop. size	Habitat
19	CB76	For. Wrzosowisko, c. 328 For. div. Tuchola	N: 53°35'31" E: 18°04'28"	B	100-year-old pine forest stand
20	CB76	For. Sarnówek, c. 5 For. div. Zamrzenica	N: 53°34'17" E: 18°04'50"	B	Edge of pine forest at communal road
21	CB76	For. Sarnówek, c. 13 For. div. Zamrzenica	N: 53°33'37" E: 18°04'23"	A	Edge of pine forest at forest road
22	CB77	For. Skrajna, c.194 For. div. Tuchola	N: 53°33'07" E: 18°06'16"	A	Edge of pine forest at forest road
23	CB95	For. Sielanka, c. 54 For. div. Zamrzenica	N: 53°25'34" E: 17°56'20"	C	Open slope at pine forest edge towards a lake and edge of forest road
24	DE35	Rogowiec, comm. Kleszczów	N: 51°16'41" E: 19°17'22"	D	Pine forest
25	EE50	Piskorzaniec, comm. Przedbórz	N: 51°03'58" E: 20°00'14"	A	Pine forest
26	EE82	Bocheniec, comm. Małogoszcz	N: 50°48'24" E: 20°18'31"	D	Pine forest

RESULTS AND DISCUSSION

CONFIRMED OR DISCOVERED LOCALITIES OF *PULSATILLA VERNALIS*

During the field research we found or confirmed 26 populations of *Pulsatilla vernalis* in the Polish lowlands (Table 1). Our results support earlier observations (Wójtowicz 2001) that the largest concentration of populations in Poland is in the Pojezierze Pomorskie (Pomeranian Lakeland) region (Fig. 2). There it occurs in the Bory Tucholskie region and in the Wysoczyzna Świecka region, neighboring to the south. These are mainly vast postglacial sandy areas covered by pine forests under forestry management by the state forest services. The relatively continuous distribution area of *P. vernalis* in this region includes 12 neighboring 10×10 km ATPOL grid squares, within which the 23 currently confirmed localities are located (Table 1).

We documented only three lowland populations outside the main concentration of the lowland populations in northern Poland (Table 1). These isolated, earlier-reported stations are in the southern part of the country: (i) the eastern part of the Kotlina Szczerowska region (Rogowiec near Bełchatów; Hereźniak *et al.* 2001), (ii) the Nizina Środkowopolska and southern edge of the

Pasma Przedborsko-Małogoskie region (Piskorzaniec; Olaczek & Wnuk 1990) and (iii) adjoining the Wzgórza Łopuszańskie region in the Wyżyna Środkowopolska upland (southernmost locality in Bocheniec; E. Bróz, pers. comm.). At this stage our field studies were focused on areas for which the available data suggested that populations probably had survived there, with the aim of inventorying the core of the existing population resources in Poland. In other parts of the historical species range in Poland the literature data indicated that the populations had a negligible chance of persisting. In Upper and Lower Silesia, *P. vernalis* was classified as extinct or near extinction (Parusel *et al.* 1996; Nowak *et al.* 2003). Many historical localities once reported from the western part of Poland (e.g., Wielkopolska) were either not confirmed after 1946 or classified as extinct (Wójtowicz 2001; P. Pawlacyk, pers. comm.). The historical localities from the northern part of the Wyżyna Śląsko-Krakowska upland (vicinity of Panki and Olsztyn near Częstochowa) were not confirmed recently either (Hereźniak 2002). The species was classified as endangered in the Kraina Świętokrzyska region, where only one population remained in Bocheniec near Małogoszcz, confirmed by Bróz (1990) and also observed after 2000 by us. In Central Poland, none of the 16 previously known localities has

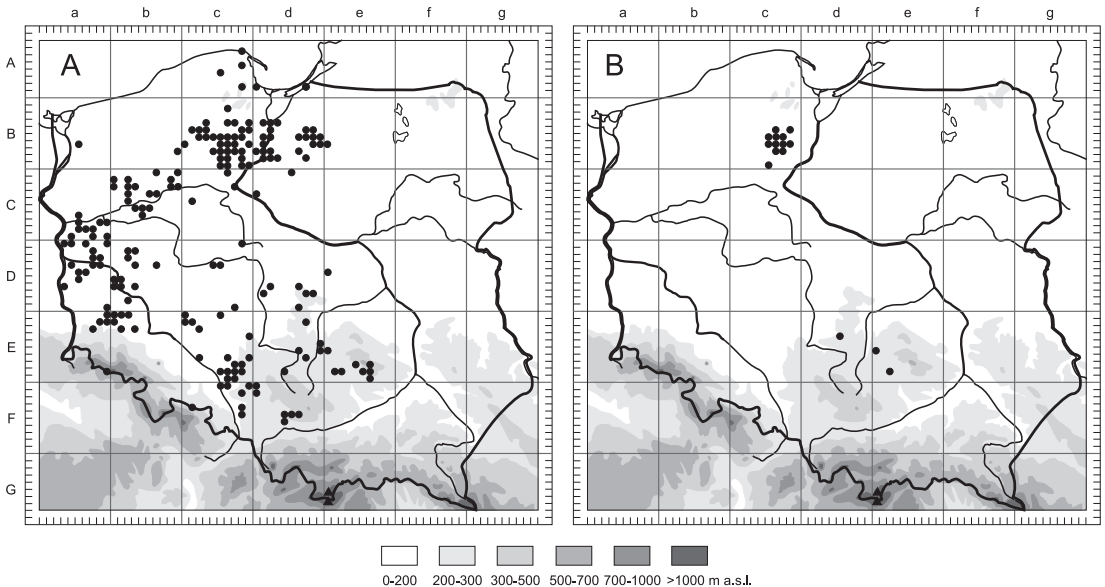


Fig 2. Distribution of *Pulsatilla vernalis* (L.) Mill. in the Polish lowlands based on the ATPOL map. A – all known records according to Zajac and Zajac (2001). B – ATPOL squares confirmed in the present study. Circles – lowland sites; triangles – mountain sites.

been confirmed (Jakubowska-Gabara & Kucharski 1999; Grzyl 2011).

CHARACTERISTICS OF LOCALITIES AND CONDITION OF POPULATIONS

The *Pulsatilla vernalis* populations in the Bory Tucholskie forest are mostly uniform in demographic structure, with mature individuals prevailing. The plants often form groups containing several neighboring rosettes. Immature plants were rarely observed. Seedlings and juvenile plants were not seen despite the presence of flowering and/or fruiting plants in most populations.

Interestingly, even though the localities are within vast forest complexes, the species usually grows in habitats undergoing more or less extensive anthropogenic disturbance resulting in higher light availability at the site (Fig. 3). Usually these are edges of poor pine forest patches (*Dicrano-Pinion*) and related semi-natural forest associations open towards forest roads or clearings along forest section borders, where patches of dry phytocoenoses with *Calluna vulgaris* (belonging to *Nardo-Callunetea*) also develop in pine forest

habitats. *P. vernalis* populations are developed within closed-canopy pine forest only sporadically, but these usually are also spots where the forest is thinned to some extent. There were also stations in anthropogenically disturbed sites such as roadsides or the slopes of railway embankments in the vicinity of forests. This may be due to the relict character of the species and the lack of optimal habitat in the extant natural communities (Ronikier *et al.* 2008).

In southern Poland, *P. vernalis* occurs in private pine forests resembling natural pine forest stands with loose and irregular canopy, where wood gathering has been based on traditional extensive, selective tree cutting typical of historical peasant forests. Such a forest management practices and the resulting type of habitat with higher light availability and locally dynamic tree turnover should be expected to enable *P. vernalis* populations to persist in the forest communities, while in the Bory Tucholskie region the populations mostly occupied forest edge habitats. The locality in Rogowiec near Belchatów, with a relatively large population, is noteworthy. In 2008 the population numbered 221



Fig 3. Examples of lowland habitats of *Pulsatilla vernalis* (L.) Mill. in Poland. A & B – edge of pine forest at forest roadside, Biała (population 10), 19 Sept. 2007, and Sarnówek (population 20), 23 Sept. 2007. C – disturbed habitat by railway at edge of pine forest, Lipowa (population 8), 19 Sept. 2007. D – pine forest, slope open towards a lake, Sielanka (population 23), 21 June 2001. E – thin pine forest, Biała (population 8), 22 July 2007. Photo: A–C & E – A. Grzyl, D – M. Ronikier.

shoots, 105 of them in a pre-generative stage. Its diversified demographic structure, with individuals in all development stages, testifies to population dynamics not observed to such an extent in any other locality (A. Grzyl, unpubl. data).

A comparison of the recently confirmed localities with all records known from Poland (in: Zając & Zając 2001) confirms the progressive extinction of the lowland populations of *Pulsatilla vernalis* in Poland. Our field studies together with published regional findings of the complete or almost complete extinction of populations make it evident that the number of ATPOL grid squares containing its localities has been greatly reduced. Moreover, most localities have very few individuals (class A in Table 1). The number of small dispersed populations is certainly higher in and around the Bory Tucholskie area but that does not significantly alter the general picture of the species' current population resources. These conclusions are in accord with observations from other countries, such as a recent detailed inventory carried out in Sweden, where 45% of the populations were deemed extinct after 1965 and more than 60% of the remaining populations have less than six plants (Åström & Stridh 2003).

A preliminary analysis of the genetic structure of the lowland populations of *P. vernalis* demonstrated average genetic diversity and low differentiation between the Bory Tucholskie populations, possibly due to the reduction of populations only in recent times (Ronikier 2002). However, some correlation of genetic diversity indices with population size was also noted. This tendency will probably become stronger with increasing spatial isolation due to the extinction of many populations, which limits potential gene exchange. Both the demographic (A. Grzyl, unpubl. data) and genetic (Ronikier 2005) data of selected populations indicate the prevalence of small-scale dispersal of diaspores, with reproduction occurring mostly in groups around parent individuals (the presence of spatially and genetically delimited groups within populations). Also, long ontogenetic development (spanning several years) preceding the generative phase, and the rare occurrence of young plants (despite regular fruiting) increase the threat to the populations.

The recorded *P. vernalis* localities are mostly close to forest roads, additionally endangering it with accidental destruction by forest management work (destruction of two sites resulting from forest road work was noted in 2008) or deliberate picking and transplanting to gardens. Effective site protection of populations at such localities is virtually impossible.

CONCLUSIONS

As a climatic relict in the Polish lowlands, *Pulsatilla vernalis* remains there mostly in small, declining populations. Their extinction risk is high, and its gradual disappearance from the area probably is irreversible. One consequence is that its eastern range limit in Poland has moved westwards, as its current geographical distribution in the region is limited to a locally more abundant group in the Bory Tucholskie forest and a few other isolated populations in the southern part of the country. *Pulsatilla vernalis* is an example of a species undergoing an exceptionally rapid decline of its population resources. We have presented grounds for proposing that its threat category in Poland should be raised from vulnerable (VU; Wójtowicz 2001) to endangered with extinction (EN). Our data are in line with the general tendency observed in the lowland part of its distribution range in other countries. Indeed, according to our observations, *P. vernalis* fulfills several of the formal criteria for the EN red list category as defined by the IUCN (2001). In particular, (i) the population size reduction over a three-generation period, taking into account the longevity of the species, may be substantial, and its causes are unlikely to cease in the future (criterion A.4); (ii) the area of occupancy does not exceed 500 km², it is characterized by high fragmentation and a continuous, documented, long-term decline in habitat area and quality (criterion B.2); and (iii) the total population size can be estimated to number fewer than 2500 mature individuals, with an observed and projected decline of mature individuals and the absence of a subpopulation containing more than 250 mature individuals (criterion C.2). The majority of the extant populations are very small,

with over half of them not exceeding 10 individuals (size category A, Table 1).

Although *Pulsatilla vernalis* has been legally protected since 1946, the lack of site protection, active management, or precise knowledge on current population resources allowing proper monitoring, may result in the extinction of this species in the lowlands. Observations to date have revealed difficulties in species protection due to the specific ecological requirements of *P. vernalis* and thus problems in establishing clear protection guidelines. The development of closed-canopy forest and degradation of sites generally are destructive, although some degree of periodic disturbance may have a positive effect (e.g., Laitinen 2008) because homogeneous closed-canopy forests are not an optimal habitat for the species. In any event, further focused chorological studies should be done to produce a comprehensive inventory of the populations of the whole area. One useful measure could be a citizen-oriented campaign to report populations of this distinctive species, involving land owners and users, tourists and others, a strategy which seems to have proved effective in other parts of the species range, especially in Scandinavia (Åström & Stridh 2003; P. Uotila, pers. comm.). Regular monitoring of populations is needed so that changes can be noted and the most valuable populations can be selected for site protection coupled with active measures (including controlled disturbance) to reduce the risk of accidental habitat destruction.

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