

# Population dynamics of *Pulsatilla patens* (L.) Mill. in a new locality in Poland

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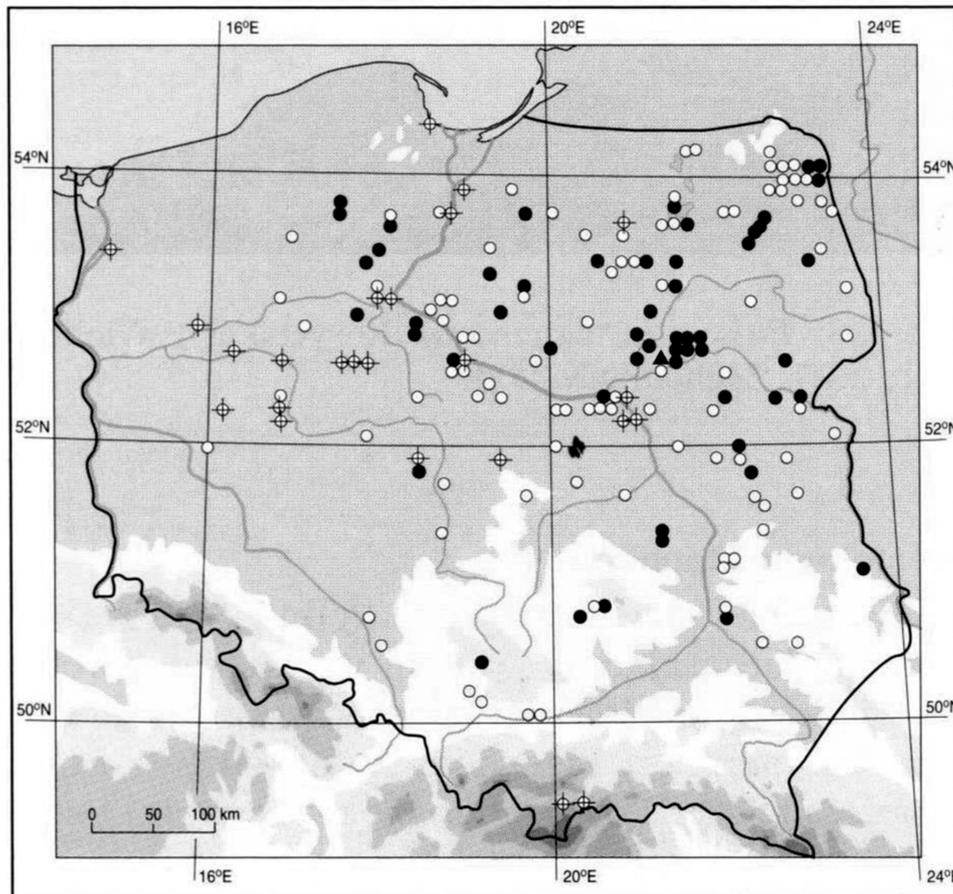
**Abstract:** A new locality of *Pulsatilla patens* (L.) Mill. in the Wyszaków-Jegiel Forest District, in the southern part of Puszcza Biała (ATPOL EC79) is described. This locality is situated on an escarpment, at the edge of *Peucedano-Pinetum* fresh pine forest with elements of *Serratulo-Pinetum* mixed pine forest and *Potentillo albae-Quercetum* steppe oak forest. Good light conditions prevail in the place of plant occurrence. Studies carried out in 2008-2015 showed an increasing trend of *P. patens* population, though, recently, this population seems to be stable. The number of species accompanying the pasque-flower also increased in this time period. It was found based on the analysis of flora directly neighbouring the clumps of the pasque-flower. During 7 years, the number of taxa increased by 31.5% on plot I and by 25% on plot II. In the years 2011-2013, the pasque-flower was represented both by flowering (1-2) and vegetative individuals. Afterwards, the plant was present only in vegetative stage. The number of its leaves varied in time. The highest number of leaves – 14 per individual – was noted in 2014, and the lowest number (1) – in 2012. The reason for a decline in the number of plant clumps in the site Dalekie and, at the same time, the greatest threat was the excavation of sand from the escarpment. In 2012, this escarpment slid down and several clumps of the pasque-flower were destroyed. Forest management and digging up by wild boars were additional factors limiting the population. To preserve the site of *P. patens*, measures of active protection should be applied.

**Key words:** *Pulsatilla patens*, Wyszaków Forest District, population dynamics, protection

## 1. Introduction

The pasque-flower (*Pulsatilla patens* (L.) Mill.) is a hemicryptophyte of circumpolar range (Meusel *et al.* 1965). Its range covers sub-polar areas of Europe, Asia and North America. In Poland, the plant was present in 453 sites (Zajac & Zajac 2001). The centre of its range is in the north-east, from where as many as 238 sites were reported. Most numerous populations are also located there (Wójtowicz 2000). The plant is rarer in Polish lowlands and uplands, where populations are composed of a few individuals. Sites in western and south-western part of Poland are still rarer (Chmura 2003). Occurrences reported earlier from Podhale and Pieniny have not been confirmed in recent years. Populations of the pasque-flower from eastern Germany (Röder & Kiehl 2006). Wójtowicz (2000) is of the opinion that European border of the range of the pasque-flower runs across Poland and its optimum is in eastern Poland (Fig. 1).

*P. patens* is a valuable and increasingly rare element of Polish flora. Since 1958, it was subject to strict conservation and, since 2004, the species has been actively protected. The pasque-flower is considered endangered in Poland and in many European countries. It is considered critically endangered in the Polish Red List of Vascular Plants (Zarzycki & Szelağ 2006) and endangered in the Polish Red Data Book of Plants (Pawlikowski & Wójtowicz 2014). Regionally, it has a status of vulnerable species in Pomorze Zachodnie (Żukowski & Jackowiak 1995), endangered species in Pomorze Gdańskie (Markowski & Buliński 2004) and critically endangered in Wielkopolska (Jackowiak *et al.* 2007). In Nizina Południowopodlaska, the pasque-flower is enlisted as extinct (Głowacki *et al.* 2003). In Europe, the plant is listed as endangered species, e.g. in Slovakia, Lithuania, Latvia, Estonia, Finland, Sweden, Russia, the Czech Republic and in Germany. The pasque-flower is included in Annex I to the Bern



**Fig. 1.** Distribution of *Pulsatilla patens* in Poland (Wójtowicz 2001)

Explanations: ● – present sites, ⊕ – historical sites, where the species is now absent, ○ – natural sites not confirmed after 1980, ▲ – new locality

Convention and in Annexes II and IV to the Habitat Directive of EU (1992).

In Poland, *P. patens* is a differential species of *Peucedano-Pinetum* pine forests (Matuszkiewicz 2006). Less frequently, it can be found at edges of *Serratulo-Pinetum*, *Quercus roboris-Pinetum* mixed pine forests or *Potentillo albae-Quercetum* steppe oak forests (Juśkiewicz-Swaczyna 2010a, 2010b; Łaska & Sienkiewicz 2010; Pawlikowski 2011). It grows in sheltered places with southern or south-western exposition (Ciosek 1999; Zych 2007), on acidic sandy soils of low nitrogen, phosphorus, magnesium and potassium content (Wójtowicz 2000).

Sites of the pasque-flower in Puszcza Biała were situated in nine ATPOL squares (Fig. 1). Out of 46 sites in this area, 35 were reported from Forest District Ostrów Mazowiecka and surrounding forests (Ciosek 1985, 1990, 1995a, 1995b, 1999). The last survey carried out in 2009 allowed to verify the occurrence of the pasque-flower in the area. Its presence was confirmed in only five sites of the district; three in Turka forest region and one in each of Nagoszewa and Brzostowa forest regions. The pasque-flower started to decline also in

other parts of Puszcza Biała. The aim of this study was to present population dynamics of *P. patens* in a new site in Dalekie near Wyszaków in years 2008-2015.

## 2. Study species

The study area is situated near Dalekie, north of Wyszaków in Masovian Province. *Pulsatilla patens* grows in a pine forest in Forest District Wyszaków-Jegiel, in southern part of Puszcza Biała (ATPOL square EC79). According to physical-geographical division of Poland (Kondracki 2013), the area is situated in Nizina Północnomazowiecka, mesoregion Międzyrzecze Łomżyńskie. This is a fragment of morainic upland situated between the valleys of the lower Narew River and the lower Bug River. According to biological-sylvan regionalization (Trampler *et al.* 1990), the study area belongs to mesoregion Wysoczyzna Łomżyńska, region Nizina Podlaska and Wysoczyzna Siedlecka, which are parts of IV Land Mazowiecko-Podlaska.

Wyszaków surroundings are situated inside the range of the central upland climate of Podlasie Region (Romer 1949). Puszcza Biała and its neighbourhood have cli-

matic conditions of the continental type. Mean annual air temperature is 7.7 °C, annual precipitation sum – 550 mm and snow cover lasts 50 to 80 days. Westerly and south-westerly winds prevail there. Vegetation period lasts from 200 to 220 days.

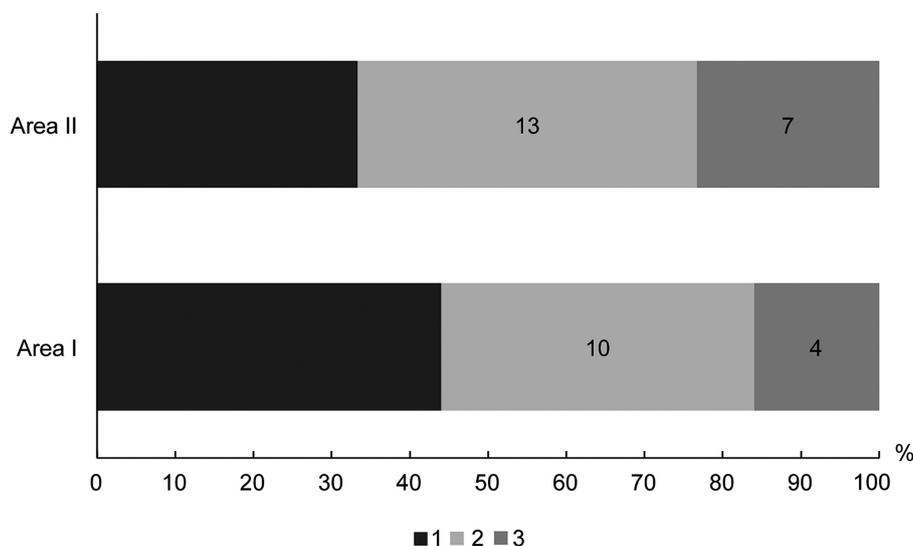
### 3. Material and methods

Studies on the population of *P. patens* were carried out in years 2008-2015. The number of individuals, flowering individuals and leaves was determined every year. To estimate changes in communities with the pasque-flower, phytosociological relevés with the commonly used Braun-Blanquet method were made every third year (2008, 2011 and 2014). Moreover, two 2 × 2 m study plots were established among clumps of the pasque-flower. In each of them, detailed floristic lists were made in years 2008 and 2014 and the occurrence frequency of particular species was estimated in a 5-grade scale (1 – very rare, 1-2 individuals, 2 – rare, several individuals, 3 – fairly frequent, ten to twenty individuals, 4 – frequent, several dozen individuals, 5 – very frequent – several dozen to several hundred individuals). Based on these data, the dynamics and competitiveness of species accompanying the pasque-flower were estimated. Plant communities were determined after Matuszkiewicz (2006) and nomenclature – after Mirek *et al.* (2002) and Ochyra *et al.* (2003).

### 4. Results

The population of *P. patens* (coverage from r to +) near Wyszaków grows on an escarpment of a railway

embankment. The area is situated at the edge of a fresh *Peucedano-Pinetum* pine forest with elements of mixed forest. In the tree stand of crown density of 70%, a layer  $a_1$  is built by *Pinus sylvestris* L., and layer  $a_2$  – by *Quercus robur* L. (coverage of both species equals 2) with a smaller contribution of *Betula pendula* Roth (Table 1). Layer b (crown density = 50%) is built by saplings of: *Pinus sylvestris* L.<sup>(2-1)</sup>, *Quercus robur*<sup>(1-2)</sup>, *Populus tremula* L.<sup>(+1)</sup>, *Betula pendula*<sup>(+1)</sup> and shrubs: *Sorbus aucuparia* L. em Hedl.<sup>(1)</sup> and *Juniperus communis* L.<sup>(1-2)</sup>. The undergrowth layer (density 70-80 %) is quite variable. Apart from species characteristic for the *Vaccinio-Picetea* (*Vaccinium myrtillus* L.<sup>(1-2)</sup>, *V. vitis-idaea* L.<sup>(2)</sup>) class, there are species characteristic and differential for fresh *Peucedano-Pinetum* pine forests (for example: *Solidago virgaurea* L.<sup>(1)</sup>, *Polygonatum odoratum* (Mill.) Druce<sup>(+1)</sup>, *Convallaria majalis* L.<sup>(1-2)</sup> and *Scorzonera humilis* L.<sup>(r+)</sup>), heathlands of the *Nardo-Callunetea* class (i.a.: *Calluna vulgaris* (L.) Hull<sup>(1-2)</sup>, *Hieracium pilosella* L.<sup>(2-3)</sup>, *Dantonina decumbens* DC.<sup>(1)</sup>), thermophilous marginal species of the *Trifolio-Geranietea* class (e.g. *Geranium sanguineum* L.<sup>(r-1)</sup>, *Peucedanum oreoselinum* (L.) Moench<sup>(r+)</sup> and *Anthericum ramosum* L.<sup>(+)</sup>) and dry sandy meadows of the *Koelerio-Corynophoretea* class (for example, *Festuca ovina* L.<sup>(+1)</sup>, *Thymus serpyllum* L. em Fr.<sup>(+1)</sup>, *Corynephorus canescens* (L.) P. Beauv.<sup>(+1)</sup> and *Rumex acetosella* L.<sup>(+1)</sup>). In the group of accompanying species, those of the largest coverage include: *Calamagrostis epigejos* (L.) Roth<sup>(1-2)</sup>, *Poa pratensis* L.<sup>(+2)</sup>, *Agrostis capillaris* L.<sup>(+3)</sup>. The moss layer of 60-70% density is mainly built by *Pleurozium schreberi* (Willd. ex Brid.) Mitt.<sup>(3-4)</sup>, *Dicranum undulatum* Schrad. ex Brid.<sup>(2-3)</sup> and lichens of the *Cladonia*<sup>(1-2)</sup> genus.



**Fig. 2.** Frequency of occurrence of flora accompanying *Pulsatilla patens* on the permanent study plots  
 Explanations: 1 – constant level, 2 – increasing frequency, 3 – decreasing frequency

**Table 1.** Phytosociological characteristics of the *Pulsatilla patens* locality in Dalekie near Wyszków

Date of the relevé		12.06.2008	15.05.2011	20.06.2014
Surface area m <sup>2</sup>		100	100	100
Layer density a	%	70	70	70
Layer density b	%	50	50	50
Layer density c	%	70	70	80
Layer density d	%	70	70	60
Number of species		39	38	48
<b>Trees and shrubs</b>				
<i>Pinus sylvestris</i>	a	2	2	2
<i>Pinus sylvestris</i>	b	2	2	1
<i>Pinus sylvestris</i>	c	1	1	+
<i>Quercus robur</i>	a <sup>2</sup>	2	2	2
<i>Quercus robur</i>	b	1	2	2
<i>Quercus robur</i>	c	1	1	+
<i>Populus tremula</i>	b	+	1	1
<i>Populus tremula</i>	c	+	1	+
<i>Betula pendula</i>	a <sup>2</sup>	1	1	1
<i>Betula pendula</i>	b	+	1	+
<i>Betula pendula</i>	c	+	+	.
<i>Sorbus aucuparia</i>	b	1	1	1
<i>Sorbus aucuparia</i>	c	+	+	+
<i>Juniperus communis</i>	b	1	2	1
<i>Juniperus communis</i>	c	+	1	1
<i>Tilia cordata</i>	c	.	.	r
<i>Padus serotina</i>	c	.	.	r
<i>Chamaecytisus ratisbonensis</i>	c	+	.	1
<i>Pulsatilla patens</i>		r	+	+
<b>Ch.D. Vaccinio-Picetea</b>				
<i>Cladonia arbuscula</i>		1	1	1
<i>Cladonia rangiferina</i>		1	2	2
<i>Pleurozium schreberi</i>		4	4	3
<i>Dicranum undulatum</i>		3	2	2
<i>Vaccinium myrtillus</i>		2	2	+
<i>Vaccinium vitis-idaea</i>		2	2	2
<i>Trientalis europaea</i>		+	+	r
<i>Melampyrum pratense</i>		r	.	+
<i>Polytrichum commune</i>		.	.	2
<b>Ch.D. Peucedano-Pinetum</b>				
<i>Convallaria majalis</i>		1	2	2
<i>Solidago virgaurea</i>		1	1	1
<i>Polygonatum odoratum</i>		+	1	1
<i>Scorzonera humilis</i>		r	+	+
<i>Peucedanum oreoselinum</i>		r	+	+
<i>Geranium sanguineum</i>		r	+	1
<i>Anthericum ramosum</i>		.	+	+
<i>Rubus saxatilis</i>		.	.	r
<b>Ch.D. Nardo-Callunetea</b>				
<i>Calluna vulgaris</i>		2	2	1
<i>Hieracium pilosella</i>		3	2	3
<i>Danthonia decumbens</i>		1	1	1
<i>Carex ericetorum</i>		+	+	+
<i>Viola canina</i>		r	+	+
<b>Ch.D. Koelerio-Coryneporetea</b>				
<i>Festuca ovina</i>		1	+	1
<i>Thymus serpyllum</i>		1	+	1
<i>Corynephorus canescens</i>		1	+	1
<i>Rumex acetosella</i>		1	+	+
<i>Helichrysum arenarium</i>		.	.	+

Date of the relevé	12.06.2008	15.05.2011	20.06.2014
Surface area m <sup>2</sup>	100	100	100
Layer density a %	70	70	70
Layer density b %	50	50	50
Layer density c %	70	70	80
Layer density d %	70	70	60
Number of species	39	38	48
<b>Accompanying:</b>			
<i>Calamagrostis epigejos</i>	2	1	1
<i>Luzula pilosa</i>	1	1	+
<i>Hieracium murorum</i>	1	1	+
<i>Anthoxanthum odoratum</i>	1	1	+
<i>Poa pratensis</i>	+	2	1
<i>Hieracium lachenalii</i>	+	+	1
<i>Galium boreale</i>	+	+	1
<i>Agrostis capillaris</i>	+	+	3
<i>Impatiens parviflora</i>	.	.	r
<i>Fragaria vesca</i>	.	.	r
<i>Pimpinella saxifraga</i>	.	.	r

The number of species present in patches together with the pasque-flower increased during 7 years (Table 1) from 39 in 2008 to 48 in 2014. The density of undergrowth increased by 10%. Young individuals of trees and shrubs like: *Tilia cordata* Mill., *Padus serotina* (Ehrh.) Borkh., *Juniperus communis*, *Chamaecytisus ratisbonensis* (Schaeff.) Rothm. and *Rubus saxatilis* L. appeared in this period. Herbs were represented, among others, by: *Helichrysum arenarium* (L.) Moench, *Impatiens parviflora* DC. and *Pimpinella saxifraga* L. The coverage degree for *Polytrichum commune* Hedw. was 2 according to the Braun-Blanquet scale. The species occurred in layer d in 2014.

Floristic analysis in 2 × 2 m plots in close neighbourhood of *P. patens* clumps showed an increase in the number of accompanying species (Table 2). The number of taxa in plot I increased from 19 to 25 (by 31.5%) and in plot II – from 24 to 30 (by 25%) during 7 years. New species of trees and shrubs appeared in both plots: *Quercus robur* (plots I and II), *Juniperus communis* (plot II) and *Chamaecytisus ratisbonensis* (plot I). In the last year, *Rumex acetosella*, *Thymus serpyllum* and *Anthoxanthum odoratum* L. appeared for the first time in plot I and *Convallaria majalis*, *Polygonatum odoratum* and *Hieracium murorum* L. appeared in plot II (Table 2). Species increasing their numbers were an important group of plants (10 species in plot I and 13 species in plot II) (Fig. 2).

*P. patens* population near Wyszaków showed increasing trends (Table 3). The number of pasque-flower shoots increased from 3 in 2008 to 11 in 2015. The greatest number of shoots was observed in 2012 (16

shoots). In five studied periods, *P. patens* occurred only in vegetative stage. Only between 2011 and 2013, generative shoots were noted (1-2 specimens). The number of leaves varied from year to year. The highest mean number of leaves per one shoot of 7.0 was noted in 2009 and 2014. The lowest mean number of leaves (4.0) was recorded in 2012 (Table 3). The highest number of leaves on a shoot (14) was observed in 2014 and the lowest (1) – in 2012.

## 5. Discussion

*P. patens* population in Dalekie near Wyszaków was not numerous and consisted of a dozen or so shoots, usually occurring in vegetative stage (only in three years of studies, flowering shoots were observed).

It was found on an escarpment at the edge of fresh *Peucedano-Pinetum* pine forest with elements of mixed *Serratulo-Pinetum* pine forest and steppe *Potentillo albae-Quercetum* oak forest. The pasque-flower from similar sites was also reported by Juśkiewicz-Swaczyna (2010a), Sokołowski (1991) and Pawlikowski (2011).

*P. patens* prefers open and sunlit places. Uotila (1969, 1996), in the study on *P. patens* ecology in Finland, concluded that individuals grew better in open places like clear cuttings, firebreaks and forest paths. Photoc conditions in the study area were good. Clumps were located in open areas, on railway embankments near a fresh pine forest. No individuals of the pasque-flower were, however, found in more shadowed areas inside the forest. The population was negatively affected

**Table 2.** Species accompanying *Pulsatilla patens* in the locality Dalekie near Wyszaków

	Area I		Area II	
	15.05.2008	12.06.2014	15.05.2008	12.06.2014
Date of the relevé				
Surface area m <sup>2</sup>	4	4	4	4
Layer density b %	10	10	-	10
Layer density c %	50	60	50	60
Layer density d %	100	70	100	80
Number of species	19	25	24	30
<b>Trees and shrubs:</b>				
<i>Juniperus communis</i> b	1	1	.	1
<i>Juniperus communis</i> c	.	+	.	+
<i>Chamaecytisus ratisbonensis</i> c	.	1	+	1
<i>Quercus robur</i> c	.	1	.	+
<i>Pulsatilla patens</i>	1	1	+	+
<b>Ch.D. Vaccinio-Picetea</b>				
<i>Cladonia arbuscula</i>	1	1	1	+
<i>Cladonia rangiferina</i>	1	1	2	1
<i>Dicranum undulatum</i>	5	3	3	3
<i>Pleurozium schreberi</i>	2	3	2	3
<i>Vaccinium vitis-idaea</i>	2	2	2	2
<i>Polytrichum commune</i>	.	.	1	2
<b>Ch.D. Peucedano-Pinetum</b>				
<i>Peucedanum oreoselinum</i>	+	r	+	+
<i>Scorzonera humilis</i>	+	+	+	+
<i>Solidago virgaurea</i>	r	+	+	+
<i>Convallaria majalis</i>	r	+	.	1
<i>Polygonatum odoratum</i>	1	+	.	1
<i>Anthericum ramosum</i>	.	.	r	+
<i>Geranium sanguineum</i>	.	.	r	+
<b>Ch.D. Nardo-Callunetea</b>				
<i>Calluna vulgaris</i>	1	+	1	+
<i>Danthonia decumbens</i>	1	+	+	+
<i>Hieracium pilosella</i>	1	2	2	1
<i>Carex ericetorum</i>	r	+		
<b>Ch.D. Koelerio-Coryneporetea</b>				
<i>Festuca ovina</i>	2	2	2	1
<i>Rumex acetosella</i>	.	+	r	+
<i>Thymus serpyllum</i>	.	+	+	+
<b>Accompanying:</b>				
<i>Calamagrostis epigejos</i>	1	1	1	+
<i>Poa pratensis</i>	+	1	1	+
<i>Anthoxanthum odoratum</i>	.	+	+	+
<i>Galium boreale</i>	.	.	r	+
<i>Taraxacum officinale</i>	.	.	r	.
<i>Hieracium murorum</i>	.	.	.	+
<i>Hieracium lachenalii</i>	.	.	.	+

by excessive development of undergrowth and moss layer. According to Röder and Kiehl (2006), substantial cover by seed plants and the presence of litter negatively affects the number of seedlings. Wójtowicz (2004), and Pilt & Kuk (2002) state that sprouting of the pasque-

flower seeds is effective in open places free from other competing plants.

The reason of the declining number of the pasque-flower clumps in Dalekie and, at the same time, the greatest risk was the excavation of sand from the escarp-

**Table 3.** Morphological parameters of *Pulsatilla patens* in the locality Dalekie near Wyszaków

Year	Number of shoots	Number of flowering individuals	Number of leaves	Number of leaves on one shoot	
				range	mean
2008	3	-	14	2-9	4.7
2009	6	-	42	4-12	7.0
2010	7	-	44	3-13	6.3
2011	9	1	44	2-10	5.0
2012	16	2	63	1-11	4.0
2013	10	1	51	2-10	5.1
2014	7	-	49	2-14	7.0
2015	11	-	51	2-10	4.6

ment. In 2012, the escarpment slid down and several clumps of the pasque-flower were destroyed. Further sand excavation may lead to complete destruction of the site.

An additional factor that may hamper the population is forest works and digging by wild boars. Cut down tree limbs and branches were observed lying in the site, which was associated with cutting and destruction of the undergrowth layer when carrying timber away.

To preserve the site of *P. patens*, measures of active protection should be applied. Based on recommendations given in Methodological Guide (Pawlikowski 2012), it is necessary to remove expansive plants in order to maintain optimum photic condition in sites of the pasque-flower. *Impatiens parviflora* appeared in one of the study plots. *Parthenocissus quinquefolia* (L.) Planch. in A & C. DC. was also observed nearby. Forest rangers should pay attention to these two species that might pose a threat to the population.

## 6. Conclusions

Based on our study, the following conclusions may be formulated:

New site of *P. patens* in Dalekie near Wyszaków is situated on an escarpment of the railway embankment in fresh *Peucedano-Pinetum* pine forest with elements of mixed pine forest and steppe oak forest. These are typical habitat conditions for this species.

Now the population of *P. patens* consists of 11 individuals. During the first five years (2008-2012), the populations showed an increasing trend. Recently, it has stabilised.

Destruction of the escarpment (sand excavation), forest works and digging by wild boars are responsible for changes in population density.

To protect the population, it is necessary to eliminate the above-mentioned factors and remove expansive species (*Impatiens parviflora*, *Parthenocissus quinquefolia*) growing together with the pasque-flower.

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