

Occurrence of the globeflower *Trollius europaeus* L. in “Łąki w Komborni” Natura 2000 site (Podkarpackie Province, SE Poland)

Maria Ziaja*, Tomasz Wójcik

Department of Natural Sciences, Faculty of Physical Education, University of Rzeszów,
Cicha 2A, 35-326 Rzeszów, Poland, *e-mail:mziaja@ur.edu.pl

Abstract. The paper presents characteristics of a meadow community with *Trollius europaeus*, threats posed to the community, and proposals for active protection thereof. The study was carried out in the “Łąki w Komborni” Natura 2000 site (PLH 180042) in the Podkarpackie Province (SE Poland). In 2015, 20 relevés were taken with the Braun-Blanquet method and they are presented in a synthetic table. Additionally, the number of clumps, the number of flowering shoots per clump, and the height of flowering shoots were determined. The community with *Trollius europaeus* was classified into the alliance *Molinion caeruleae* with *Selinum carvifolia*, *Galium boreale*, *Succisa pratensis*, *Betonica officinalis*, *Gladiolus imbricatus*, and *Carex tomentosa* as characteristic species. Scrub species, in particular *Filipendula ulmaria*, had a substantial share, which indicated long-term abandonment of land use. The community also comprised rush species (*Carex gracilis*, *Phragmites australis*) and a numerous group of species from the order *Arrhenatheretalia* (e.g. *Geranium pratense*, *Alchemilla monticola*, *Galium mollugo*, *Arrhenatherum elatius*) and the class *Molinio-Arrhenatheretea* (e.g. *Lathyrus pratensis*, *Alopecurus pratensis*, *Ranunculus acris*, *Poa pratensis*). Abandonment of extensive land use leading to progressive secondary succession is the major threat to phytocoenoses with *Trollius europaeus*. To preserve meadows with *Trollius europaeus*, active protection involving mowing and removal of biomass is recommended.

Key words: *Molinion caeruleae*, plant communities, protected species, active protection, threats.

1. Introduction

The globeflower (*Trollius europaeus* L.) species has a Euro-Siberian range covering nearly the entire Europe and western Siberia (Piękoś-Mirkowa & Mirek 2003; Zajac & Zajac 2009). In Poland, its occurrence is fragmented, with the greatest density in Lubelszczyzna region, whereas in Podkarpackie the species is very rare (Zajac & Zajac 2001). In our country, *Trollius europaeus* is a strictly protected species (Regulation of the Minister of the Environment... 2014). Given the progressive loss of its habitats, *Trollius europaeus* has been included in many regional lists of endangered species. In Opolszczyzna, it is regarded as a critically endangered (CR) species (Nowak et al. 2008). In Lower Silesia (Kački et al. 2003), Śląskie Province

(Bernacki et al. 2000; Parusel & Urbisz 2012), Western Pomerania (Żukowski & Jackowiak 1995), Wielkopolska (Jackowiak et al. 2007), central Poland (Jakubowska-Gabara & Kucharski 1999), and in the area of Południowo-podlaska Lowland (Głowacki et al. 2003), *Trollius europaeus* represents the group of vulnerable (VU) taxa. With the low-risk category (LR), it can be found on the list of threatened-with-extinction and endangered species from the Lublin Upland, Roztocze, Polesie Lubelskie region, and Western Volhynia (Kucharczyk & Wójcik 1995). It has also been listed with the VU category in the Red Book of the Łódź Province (Kołodziejek 2012).

Trollius europaeus is a characteristic species for wet meadows from the order *Molinietalia caeruleae* and the association *Polygono bistorte-Trollietum europaei*. It also occurs at forest margins and in fringe communities (Ma-

tuszkiewicz 2008); it is less frequent in rush communities (Kochanowska & Gamrat 2007). The species grows on moist, eutrophic soils with acidic to alkaline pH. It prefers full light and moderately cold climate conditions (Zarzycki et al. 2002).

Molinion caeruleae meadows are one of the richest meadow communities and a habitat for many rare and protected plant species (Trąba 1997; Kołodziejek & Michalska-Hejduk 2004; Řezníčková 2007; Suder 2007; Bochnak 2011; Kaćki & Michalska-Hejduk 2010; Kulik 2014). They also represent the most valuable semi-natural communities in Poland and Europe (Kaćki & Załuski 2004; Zelnik 2005; Havlová 2006; Michalska-Hejduk & Kopeć 2012). *Molinion caeruleae* phytocoenoses occupy specific moist habitats characterised by temporarily stagnant water in spring and low water levels in summer. They are semi-natural communities associated with human economic activity. They require appropriate agrotechnical treatments that will contribute to conservation of their floristic and phytocoenotic diversity (Załuski 2007).

In the second half of the 20th century, meadows underwent rapid transformation. Disappearance or transformation of meadow communities is usually caused by anthropogenic factors, e.g. abandonment of management, intensive fertilisation, or changes in water relations. This process has been progressing rapidly both in Poland and across Europe (Kotąńska 1993; Michalska-Hejduk 2001; Załuski 2007; Řezníčková 2007; Sienkiewicz-Paderewska et al. 2012, Trąba & Wolański 2012). The reduction of the surface area of *Molinion caeruleae* meadows has resulted in a decline in biodiversity and loss of localities of a number of rare species (Jakubowska-Gabara & Kucharski 1999; Bochnak 2011; Michalska-Hejduk & Kopeć 2012; Trąba & Wolański 2012; Kulik 2014). Based on the Habitats Directive, variable-moisture *Molinion caeruleae* meadows have been classified as habitats that should be protected as Natura 2000 areas (Directive 1992; Kaćki & Załuski 2004).

The aim of the study was to determine the species composition and characteristics of a community with *Trollius europaeus* located in “Łąki w Komborni”, a Natura 2000 site, and to indicate threats as well as methods for active protection of the community.

2. Materials and methods

The field study was conducted in 2015 in the “Łąki w Komborni” Natura 2000 site (PLH 180042) located in Krościenko Wyżne Commune, Podkarpackie Province, (SE Poland). According to the physical-geographical regionalisation by Kondracki (2011), the study area belongs to the Jasło-Krosno Basin mesoregion, which is a part of the Western Carpathians. In geobotanical terms, the area is a part of the Jasło-Sanok Depression (Oklejewicz 1993,

1996). The study area comprises the largest *Trollius europaeus* locality in the Jasło-Sanok Depression (Łuczaj & Oklejewicz 2001), and the main aim of protection of this area is to conserve the variable-moisture *Molinion caeruleae* meadows (Łuczaj 2011).

The investigations were based on 20 relevés taken with the commonly used Braun-Blanquet method. The nomenclature of vascular plants followed that proposed by Mirek et al. (2002) and moss names were adopted from Ochrya et al. (2003). The phytosociological affiliation of species followed the system developed by Matuszkiewicz (2008). Additionally, the number of clumps, the number of flowering shoots per clump, and the height of flowering shoots in *Trollius europaeus* were determined.

3. Results

The localities with *Trollius europaeus* in the study area are located within stands of disturbed *Molinion caeruleae* meadows from the alliance *Molinion caeruleae*. Variable moisture conditions and long-term abandonment of these meadows have contributed to development of a mosaic of diverse habitats. The meadow community in this area is one of the richest phytocoenoses in terms of the floristic composition, since the number of species per relevé ranged from 15 to 50 with an average number of 33. The total number of species in the community was 87 (Table 1). Six species from the alliance *Molinion caeruleae* were noted, the most frequent of which were *Galium boreale* (S=III), *Selinum carvifolia* (S=IV), and *Succisa pratensis* (S=III). Other species, i.e. *Carex tomentosa*, *Gladiolus imbricatus*, and *Betonica officinalis*, were characterised by low stability and insignificant coverage.

A substantial share in the community was noted in the case of scrub species characteristic for the alliance *Filipendulion ulmariae*. *Filipendula ulmaria*, which was a dominant or co-dominant species in all the relevés, was particularly abundant (S=V, D=3000). High stability and coverage were also exhibited by *Veronica longifolia* (S=V, D=467), whereas the share of *Lythrum salicaria* and *Lysimachia vulgaris* was inconsiderable.

Cirsium rivulare (S=V, D=1876), a species characteristic for the alliance *Calthion*, and *Geum rivale*, i.e. a differential species with stability degree IV, were the permanent elements of the community. There were few representatives of the other species of this alliance (*Juncus conglomeratus*, *Myosotis palustris*, *Cirsium canum*), and they formed small clusters.

Species associated with *Molinion caeruleae* meadows were also represented by *Sanguisorba officinalis* (S=V) and *Serratula tinctoria* (S=III) from the order *Molinietales*. The order with stability degree V included *Angelica sylvestris* and *Lychnis flos-cuculi*, whereas *Deschampsia*

Table 1. Social structure of the community with *Trollius europaeus* L.

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Constancy [S]	Cover coefficient [D]
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Area of relevé [m ²]	279	280	280	280	280	280	280	278	278	277	276	275	274	278	276	276	272	273	272	275		
Altitude [m a.s.l.]	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06		
Date (Day, month, year)	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015		
Cover of shrub layer b [%]	3	2	0	2	0	0	0	0	0	0	0	0	10	5	15	10	0	0	0	0		
Cover of herb layer [%]	100	100	100	100	100	100	100	100	100	100	85	100	100	100	100	100	100	100	100	90		
Cover of moss layer d [%]	2	2	2	2	1	1	1	1	0	2	0	0	0	0	0	0	0	0	0	0		
Number of species	50	40	46	43	38	40	31	37	33	29	15	27	18	32	31	31	33	37	27	19		
<i>Trollius europaeus</i>	+	+	1.2	4.3	3.2	2.2	5.4	3.3	2.2	1.2	4.3	1.3	+	2.2	2.3	3.3	2.2	2.2	1.3	1.3	V	2876
ChAll. <i>Molinietalia caeruleae</i>																						
<i>Selinum carvifolia</i>	.	1.2	+	1.2	2.2	2.2	+	+	+	+	+	1.2	1.2	.	+	1.2	+	+	.	.	IV	304
<i>Galium boreale</i>	1.2	3.2	2.2	3.2	3.2	3.2	+	+	.	+	+	.	.	.	.	.	.	.	3.2	1.2	III	1077
<i>Succisa pratensis</i>	.	.	+	+	+	+	.	+	.	+	.	.	.	.	.	1.1	1.2	+	.	.	III	53
<i>Betonica officinalis</i>	2.3	2.3	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	II	176
<i>Gladiolus imbricatus</i>	.	1.1	+	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	2.1	II	114
<i>Carex tomentosa</i>	.	+	+	+	+	+	+	.	.	.	.	+	.	+	.	.	.	.	.	.	II	4
ChAll. <i>Filipendulion ulmariae</i>																						
<i>Filipendula ulmaria</i>	2.3	3.3	3.3	2.3	2.2	2.2	2.2	2.2	3.2	4.3	1.2	4.3	4.3	2.2	3.2	2.2	3.2	4.3	2.2	2.3	V	3000
<i>Veronica longifolia</i>	.	+	+	1.1	.	2.1	+	+	+	1.2	1.1	+	3.1	+	+	+	+	2.1	.	1.1	V	467
<i>Lythrum salicaria</i>	.	.	.	+	.	.	+	+	+	+	+	+	+	+	.	.	.	.	.	+	III	5
ChAll. <i>Calthion palustris</i>																						
<i>Cirsium rivulare</i>	1.3	1.2	2.2	3.2	3.2	3.2	3.2	3.2	2.2	1.2	.	1.2	1.2	3.2	2.2	2.2	2.2	3.2	+	+	V	1876
<i>Juncus conglomeratus</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	1.3	+	+	+	+	.	.	II	27
<i>Myosotis palustris</i>	.	.	.	.	.	.	+	+	+	+	.	.	.	+	.	.	.	+	.	.	II	3
<i>D. Geum rivale</i>	+	.	.	+	+	.	+	+	+	+	.	+	.	.	1.1	+	1.2	1.2	+	.	IV	80
ChO. <i>Molinietalia caeruleae</i>																						
<i>Sanguisorba officinalis</i>	+	2.2	2.2	1.2	2.1	1.2	2.2	1.2	1.2	1.2	1.2	.	.	+	1.1	1.1	2.2	1.2	1.2	2.1	V	688
<i>Lychnis flos-cuculi</i>	+	+	+	+	+	+	+	1.1	+	+	.	+	+	2.2	+	+	+	1.1	+	.	V	145
<i>Angelica sylvestris</i>	+	+	+	1.2	1.2	1.1	+	1.2	1.2	+	.	+	.	+	+	+	+	+	+	+	V	132
<i>Deschampsia caespitosa</i>	1.3	+	+	1.3	.	+	1.2	1.3	1.2	.	.	.	.	+	+	+	+	+	1.3	.	IV	154
<i>Serratula tinctoria</i>	.	1.1	2.2	+	.	+	1.2	1.2	1.2	+	.	.	.	+	+	.	2.2	+	+	.	III	278
<i>Climacium dendroides</i> [d]	+	+	+	+	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	II	4
ChO. <i>Arrhenatheretalia elatioris</i>, ChAll. <i>Arrhenatherion elatioris</i>*																						
* <i>Geranium pratense</i>	2.2	2.3	1.2	3.3	1.2	2.2	+	1.2	1.2	1.2	1.2	+	+	+	+	+	.	+	+	+	V	604
* <i>Alchemilla monticola</i>	1.2	1.2	1.2	1.2	+	2.2	1.2	1.2	1.2	+	+	+	.	+	+	+	+	+	+	+	V	268
* <i>Galium mollugo</i>	.	.	1.2	+	+	1.2	+	1.2	1.2	+	.	+	+	.	+	+	+	+	.	.	IV	105
<i>Heracleum sphondylium</i>	+	+	+	+	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+	IV	7,5

Successive number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
<i>*Campanula patula</i>	+	+	+	·	·	+	·	+	+	·	·	+	·	·	+	+	+	+	+	+	IV	6
<i>*Arrhenatherum elatius</i>	2.3	+	2.2	2.2	3.2	3.2	+	+	+	+	·	·	·	·	·	·	·	·	·	·	III	640
<i>Pimpinella major</i>	1.2	+	1.2	+	1.2	2.2	·	·	+	·	+	+	·	·	·	+	·	·	1.2	+	III	190
<i>Achillea millefolium</i>	+	+	1.2	+	+	·	·	·	+	·	·	·	·	·	+	·	+	·	·	·	III	29
<i>Dactylis glomerata</i>	+	·	+	+	+	+	·	+	+	+	·	·	·	·	·	·	·	·	·	·	II	4
<i>Leucanthemum vulgare</i>	+	·	·	+	+	·	·	·	·	·	·	·	·	+	·	·	+	+	+	·	II	3,5
<i>*Knaulia arvensis</i>	+	+	+	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	II	3
ChCl. Molinio-Arrhenatheretea																						
<i>Lathyrus pratensis</i>	2.2	1.2	1.2	2.2	2.2	2.2	1.2	1.2	+	+	+	1.2	+	1.2	+	+	+	1.2	1.1	+	V	553
<i>Alopecurus pratensis</i>	1.2	+	+	+	+	+	·	+	+	+	+	+	+	·	·	+	·	+	2.2	·	IV	118
<i>Ranunculus acris</i>	+	+	+	+	1.2	1.2	+	+	+	+	+	·	·	·	+	·	+	·	·	·	IV	56
<i>Poa pratensis</i>	+	1.2	+	+	+	·	·	+	+	+	+	+	+	·	+	1.2	+	+	+	·	IV	56
<i>Holcus lanatus</i>	1.3	·	+	+	+	+	+	+	+	+	·	·	·	·	+	+	+	+	·	·	III	55
<i>Rumex acetosa</i>	+	+	+	+	+	+	+	+	+	+	·	·	·	+	+	+	+	+	·	·	III	5,5
<i>Ranunculus repens</i>	1.2	·	1.2	+	+	+	+	·	·	·	·	·	·	2.3	·	1.2	·	·	·	·	II	164
<i>Centaurea jacea</i>	+	+	·	+	+	+	·	+	+	+	·	·	·	·	·	·	·	·	·	·	II	3,5
<i>Vicia cracca</i>	+	·	·	·	·	·	·	·	+	+	·	·	·	·	·	+	+	·	·	·	II	3
<i>Cerastium holosteoides</i>	+	·	+	+	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	II	2,5
<i>Festuca pratensis</i>	+	+	·	·	+	+	+	·	·	+	·	·	·	·	·	·	·	·	·	·	II	2,5
ChCl. Phragmitetea																						
<i>Carex gracilis</i>	+	·	·	·	+	·	1.2	+	4.3	3.3	+	4.3	+	4.3	1.3	4.3	4.3	2.2	3.3	+	IV	1928
<i>Phragmites australis</i>	+	2.2	1.2	2.2	+	1.2	·	·	·	·	·	1.2	2.2	1.2	4.3	·	·	+	1.2	+	IV	702
Other species																						
<i>Ranunculus auricomus</i>	·	+	+	·	·	+	·	+	+	+	+	+	+	·	·	·	+	+	+	1.1	IV	31
<i>Veronica chamaedrys</i>	1.2	+	+	+	+	+	+	+	+	·	·	·	·	·	+	·	·	+	·	·	III	30
<i>Salix cinerea</i> [b]	+	·	·	·	·	·	·	·	·	·	·	·	2.3	+	2.3	2.2	·	·	·	·	II	263
<i>Carex spicata</i>	·	1.1	+	+	+	+	1.2	·	·	·	·	+	·	+	·	·	·	·	·	·	II	53
<i>Primula elatior</i>	+	·	·	·	+	·	·	+	·	·	·	·	·	·	·	·	·	1.3	·	+	II	27
<i>Potentilla erecta</i>	·	+	+	·	·	+	+	·	·	·	·	·	·	·	·	+	+	·	·	·	II	3,5
<i>Cruciata glabra</i>	·	+	+	·	+	+	·	·	·	·	·	+	·	·	·	·	+	·	·	·	II	3
<i>Plagiomnium elatum</i> [d]	+	+	+	+	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·	II	3

Sporadic species: ChAll. *Filipendula ulmariae* – *Lysimachia vulgaris* 16 (+), 17 (+), 18 (+); ChAll. *Calthion palustris* – *Cirsium canum* 12 (+); ChO. *Molinietalia caeruleae* – *Lotus uliginosus* 4 (+); *Equisetum palustre* 14 (+); ChO. *Arrhenatheretalia elatioris* – *Tragopogon orientalis* 1 (+); ChCl. *Molinio-Arrhenatheretea* – *Lysimachia nummularia* 8 (+), 14 (1.1), 18 (+); *Poa trivialis* 1 (+), 9 (+), 14 (+), 18 (+); *Festuca rubra* 1 (1.2), 2 (1.3), 18 (+); *Trifolium pratense* 4 (+); *Potentilla anserina* 14 (+); ChCl. *Phragmitetea* – *Carex vulpina* 10 (1.3); *Galium palustre* 14 (+); Others – *Carex nigra* 13 (3.3), 16 (+), 17 (+), 18 (+); *Alnus glutinosa* [b] 14 (1.1), 15 (+); *Calamagrostis epigejos* 3 (1.2); *Anthoxanthum odoratum* 3 (+), 5 (+), 6 (+), 7 (+); *Galium verum* 2 (+), 3 (+), 6 (+), 18 (+); *Luzula campestris* 3 (+), 4 (+), 6 (+), 7 (+); *Symphitium officinale* 1 (+), 13 (+), 14 (+), 15 (+); *Rhynchos catarticus* [b] 2 (+), 4 (+); *Crataegus* sp. [b] 1 (+), 4 (+); *Epilobium hirsutum* 11 (+), 19 (+); *Solidago gigantea* 17 (+), 18 (+); *Ajuga reptans* 18 (+); *Briza media* 3 (+); *Euonymus europaea* [b] 1 (+); *Hypericum maculatum* 1 (+); *Pádis avium* [b] 1 (+); *Salix triandra* [b] 15 (+); *Stellaria graminea* 6 (+); *Alliaria petiolata* 1 (+); *Cirsium arvense* 1 (+); *Galium aparine* 12 (+); *Melandrium album* 1 (+); *Urtica dioica* 1 (+).

caespitosa was noted less frequently and was characterised by stability degree IV. Furthermore, the moss layer comprised sparse representatives of *Climacium dendroides*.

A significant share of species characteristic for fresh meadows from the order *Arrhenatheretalia elatioris* and the alliance *Arrhenatherion elatioris* was noted. High stability degrees were exhibited by *Geranium pratense*, *Alchemilla monticola*, *Galium mollugo*, *Campanula patula*, and *Heracleum sphondylium*.

Species characteristic for the class *Molinio-Arrhenatheretea* represented a high share in the community. *Lathyrus pratensis* reached the highest stability degree and cover coefficient, whereas *Alopecurus pratensis*, *Ranunculus acris*, and *Poa pratensis* exhibited stability degree IV and inconsiderable coverage. The occurrence of other diagnostic species was marginal.

The phytocoenoses with *Trollius europaeus* were characterised by the presence of grass and sedge rush species. High stability and coverage coefficients were noted for *Carex gracilis* and *Phragmites australis*, which served a function of a dominant species in some stands.

Accompanying species with high stability but low coverage values were represented by *Ranunculus auricomus* and *Veronica chamaedrys*. This group also comprised single specimens of trees and shrubs, i.e. *Alnus glutinosa*, *Rhamnus catharticus*, *Crataegus* sp., *Euonymus europaea*, *Padus avium*, and *Salix triandra*.

Besides *Trollius europaeus*, two protected species *Gladiolus imbricatus* and *Primula elatior* were noted in the community.

In the study area, in total 1010 *Trollius europaeus* clumps were found in the relevés. The results of measurements of selected individual features of the population are presented in Table 2.

4. Discussion and conclusions

The analysed meadow stands in the "Łąki w Komborni" Natura 2000 site, which was characterised by the presence of *Trollius europaeus*, were classified as variable-moisture *Molinion caeruleae* meadows. In the meadow vegetation in Poland, *Trollius europaeus* most frequently occurs in the association *Molinietum caeruleae*, where it reaches the highest coverage (Kochanowska 1995; Kochanowska & Gamrat 2007; Bochnak 2011). In the northern part of the Śląskie Province, Kołodziejek and Michalska-Hejduk (2004) described a community with the globeflower as a typical variant of the sub-association *Molinietum caeruleae cirsietosum rivularis* due to the permanent presence of the differential species *Cirsium rivulare*. In turn, in the south-eastern part of the Silesian Upland, Babczyńska-Sendek (2009) reported the association *Cirsietum rivularis* from the alliance *Calthion palustris* with the ana-

Table 2. Measurement of individual features of populations of *Trollius europaeus* L.

Population <i>Trollius europaeus</i> L.	Min.	Max.	Mean
Number of clumps in relevé	1	250	50
Number of flowering shoots per clump	5	14	10
Height of flowering shoots [cm]	55	112	86.5

lysed species. In Western Pomerania, phytocoenoses with *Trollius europaeus* were classified into the association *Polygono bistortae-Trollietum europaei* comprising two sub-associations *Polygono-Trollietum caricetosum nigrae* and *Polygono-Trollietum filipenduletosum* (Ćwikliński & Jasnowski 1997).

The species was also noted in rush communities, where it formed single clumps limited by expansion of *Phragmites australis* (Kochanowska 1995; Kochanowska & Gamrat 2007).

Due to the abandonment of the *Molinion caeruleae* meadows, the community is rapidly colonised by *Filipendula ulmaria*, i.e. a species with a specific biology of development facilitating encroachment onto unmown meadows within a short time. Kochanowska (1995) described the occurrence of the globeflower in the association *Filipendulo-Geranium* from the alliance *Filipendulion ulmariae* in central Pomerania. In turn, Dembicz et al. (2011) reported stands in central Poland with the globeflower in scrub communities from the alliance *Molinion caeruleae* comprising abundant *Filipendula ulmaria* specimens.

Furthermore, literature provides information about the distribution of *Trollius europaeus* in forest communities from the order *Quercio-Fagetalia* and fringe communities from the order *Glechometalia* (Ciosek et al. 2013). The authors suggest that the occurrence of the globeflower in forest communities supports the hypothesis that these are the primary habitats of the species in Europe. Primeval forests in Europe had a character of woodland pastures with open grasslands, whereas semi-natural meadows remaining after forest clearing are a secondary habitat requiring extensive management.

Investigations of the genus *Trollius* are also focused on determination of its ecological structure and morphological variability, which are used for assessment of the condition of the population and possibilities of its development (Antkowiak 1999, 2002; Juśkiewicz-Swaczyna et al. 2008; Muncaciu et al. 2010; Kostrakiewicz 2009; Kostrakiewicz-Gierałt 2012).

In the study area, in total 1010 *Trollius europaeus* clumps were found and their number ranged from 1 to 250 per relevé (50 on average). The number of flowering shoots per clump was in the range from 5 to 14 (10 on average). Similar results were obtained in other regions of Poland: from several to 20 inflorescence shoots per clump in cen-

tral Pomerania (Kochanowska 1995), from 0 to 15 generative shoots in the Olsztyn Lakeland (Juśkiewicz-Swaczyna et al. 2008), and on average 7 flowering shoots in the north-western Poland, as reported by Antkowiak (1999). In turn, Kochanowska and Gamrat (2007) highlighted the contribution of mowing to development of a great number of flowering shoots (from 20 to 40).

The height of *Trollius europaeus* in the analysed phytocoenoses ranged from 55 to 112 cm, (86.5 on average). The height of flowering shoots was estimated at 78-110 cm by Kochanowska (1995), 43-75 cm by Antkowiak (2002), and 22-60 cm by Juśkiewicz-Swaczyna et al. (2008). The greatest height of generative shoots (100-112 cm) was noted in the Chociel valley by Kochanowska & Gamrat (2007), who associated the results of the biometric measurements with meadow mowing practices.

Over the last years, semi-natural *Molinion caeruleae* meadows have been disappearing at an increasing rate, and phytocoenoses have been undergoing species impoverishment (Zalewska 1997; Kochanowska 2005; Havlová 2006; Załuski 2007; Řezníčková 2007; Michalska-Hejduk 2001; Michalska-Hejduk & Kopec 2012; Kącki 2007, 2012; Trąba & Wolański 2012; Sienkiewicz-Paderewska et al. 2012; Kulik 2014). *Trollius europaeus* populations present in meadow communities are threatened with extinction. Abandonment of extensive land use, triggering progressive secondary succession, is the major threat to the species. Consequently, the structure and function of the community are disturbed, characteristic rare species disappear, and the area of these communities gradually decreases (Ćwikliński & Jasnowski 1997; Tomaszewska 2003; Kochanowska 2005; Kochanowska & Gamrat 2007; Bochnak 2011; Michalska-Hejduk & Kopec 2012; Lemke et al. 2015).

With time, unmanaged *Molinion caeruleae* meadows are transformed into scrub communities from the alliance *Filipendulion*, which was observed by Kochanowska (1995) in central Pomerania, Sienkiewicz-Paderewska et al. (2012) in the Biebrza valley, and Kulik (2014) in the Łęczna-Włodawa Lakeland. The long-term investigations conducted by Falińska (1989) confirmed that *Filipendula ulmaria* is the first to encroach unmown sites. In unmanaged *Molinion caeruleae* meadows, a decline in the number of species characteristic for the alliance *Molinion caeruleae* and, on the other hand, an increase in the number of species representing other accompanying communities can be observed (Kącki & Michalska-Hejduk 2010). Such processes can also be observed in the study area, where *Filipendula ulmaria* was one of the dominant species. Bochnak (2011) and Kochanowska & Gamrat (2007) noted that the development of shrubs and trees largely inhibited the seed germination and the growth of juvenile *Trollius europaeus* specimens, which was confirmed by the study of Lemke et al. (2015).

A severe threat is also posed by mown biomass remaining on the soil surface, which greatly limits species diversity and simultaneously promotes expansion of other species (Kotańska 1993; Kochanowska 2005), induces changes in soil chemical properties, and inhibits germination of *Trollius europaeus* seeds (Lemke et al. 2015). Digging out and transplanting *Trollius europaeus* to home gardens, which was noted in the study area, is another danger (Tomaszewska 2003).

Intensive mowing and fertilisation are not recommended for conservation of *Molinion caeruleae* meadows, as they cause impoverishment of the species composition of the phytocoenoses and transformation toward communities with dominance of grasses, e.g. *Deschampsia caespitosa* (Kotańska 1993; Kącki & Załuski 2004; Suder 2007; Kulik 2014). A common threat is the complete change in the land use category. Ecosystems undergo complete destruction and meadows are converted into arable land (Załuski 2007). Such activities were noted in the study area as well, where some of the meadow stands had been ploughed and converted into crop fields.

Under rational meadow management, i.e. mowing and removal of biomass, *Trollius europaeus* has a chance to compete successfully with scrubs, e.g. *Filipendula ulmaria* and *Anthriscus sylvestris*, or tree and shrub seedlings (Kochanowska 2005; Kochanowska & Gamrat 2007; Lemke et al. 2015).

Molinion caeruleae meadows are subjected to irreversible changes caused by human activity. Abandonment of land use immediately triggers the process of natural succession towards scrub and forest communities. Therefore, active protection measures, which include management practices aimed at conservation of these phytocoenoses, should be employed.

The results of the current study indicate a number of threats for the *Trollius europaeus* population, the most significant of which is the progressing secondary succession. Conservation of this vulnerable species will be possible upon application of active protection practices, i.e. annual or biennial late mowing and removal of mown biomass. Additionally, permanent monitoring that will reveal changes in the phytocoenoses is recommended.

References

- Antkowiak W., 1999, Struktura ekologiczna populacji pełnika europejskiego (*Trollius europaeus* L. subsp. *europaeus*) w Polsce północno-zachodniej [Ecological structure of *Trollius europaeus* L. subsp. *europaeus* populations in north-western Poland], Roczniki Akademii Rolniczej w Poznaniu – CCCXVI, Bot. 2: 3-17.

- Antkowiak W., 2002, Międzypopulacyjna zmienność populacji pełnika europejskiego (*Trollius europaeus* L. subsp. *europaeus*) w Polsce północno-zachodniej [Interpopulation variability of globe flower (*Trollius europaeus* L. subsp. *europaeus*) in north-western Poland], Roczniki Akademii Rolniczej w Poznaniu – CCCXLVII, Bot. 5: 3-14.
- Babczyńska-Sendek B., 2009, Significance of protection of the meadow and grassland communities for maintenance the floristic diversity in the area of the south-eastern Silesian Upland (Poland), Biodiversity Research and Conservation 13: 49-60.
- Bernacki L., Nowak T., Urbisz A., Urbisz A. & Tokarska-Guzik B., 2000, Rośliny chronione, zagrożone i rzadkie we florze województwa śląskiego [Protected, threatened and rare plants in the flora of Silesia Province –Voivodship], Acta Biologica Sielsiana 35: 78-107.
- Bochnak D., 2011, Stan populacji rzadkich gatunków roślin naczyniowych w zespole *Molinietum caeruleae* w okolicach Tyńca i Sidziny [Populations status of rare vascular plants in *Molinietum caeruleae* association in vicinity of Tynec and Sidzina (S Poland)], Chrony Przyrodę Ojczyzną 67(3): 210-217.
- Ciosek T.M., Krechowski J. & Piórek K., 2013, Pełnik europejski *Trollius europaeus* L. w zbiorowiskach leśnych i okrajkowych północnej części Niziny Południowopodlaskiej [Globe flower *Trollius europaeus* L. in forest and forest edge communities in the northern part of the Południowopodlaska Lowland], Leśne Prace Badawcze 74(3): 233-243.
- Ćwikliński E. & Jasnowski M., 1997, Łąki pełnikowe *Polygono bistortae-Trollietum europaei* na Pomorzu Zachodnim [Globe flower meadows *Polygono bistortae-Trollietum europaei* in western Pomerania], Ochrona Przyrody 54: 59-72.
- Dembicz I., Kapler A., Kozub Ł. & Zaniewski P., 2011, New locality of *Trollius europaeus* L. and *Gladiolus imbricatus* L. near Sochocin by Płońsk (central Poland), Opole Scientific Society, Nature Journal 44: 36-46.
- Dyrektywa 1992, Dyrektywa Rady 92/43/EWG z dnia 21 maja 1992 roku w sprawie ochrony siedlisk naturalnych oraz dzikiej fauny i flory [Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wilde fauna and flora].
- Falińska K., 1989, Plant population processes in the course of forest succession in abandoned Meadows. I. Variability and diversity of floristic compositions and biological mechanisms of species turnover, Acta Societatis Botanicorum Poloniae 58(3): 439-465.
- Głowacki Z., Falkowski M., Krechowski J., Marciniuk J., Marciniuk P., Nowicka-Falkowska P. & Wierzbna M., 2003, Czerwona lista roślin naczyniowych Niziny Południowopodlaskiej [The red list of vascular plants of the Południowopodlaska Lowland], Chrony Przyrodę Ojczyzną 59(2): 5-41.
- Havlová M., 2006, Syntaxonomical revision of the Molinion meadows in the Czech Republic, Preslia 78(1): 87-101.
- Jackowiak B., Celka Z., Chmiel J., Latowski K. & Żukowski W., 2007, Red list of vascular flora of Wielkopolska (Poland), Biodiversity Research and Conservation 5-8: 95-127.
- Jakubowska-Gabara J. & Kucharski L., 1999, Ginące i zagrożone gatunki flory naczyniowej zbiorowisk naturalnych i półnaturalnych w Polsce Środkowej [Endangered and threatened vascular plants in natural and seminatural communities in Central Poland], Fragmenta Floristica et Geobotanica, Series Polonica 6: 55-74.
- Juśkiewicz-Swaczyna B., Endler Z. & Szczesna S., 2008, Structure of a population of *Trollius europaeus* L. at a locality near Barczewo in the Olsztyn Lakeland, Polish Journal of Natural Sciences 23(3): 598-610.
- Kącki Z., 2007, Comprehensive syntaxonomy of *Molinia* meadows in southwestern Poland, Acta Botanica Silesiaca, Monographiae 2: 1-136.
- Kącki Z., 2012, Variability and long-term changes in the species composition of *Molinia* meadows in Poland: a case study Rusing a large data set from the Polish Vegetation Database. Acta Botanica Silesiaca, Monographiae 7: 1-144.
- Kącki Z., Dajdok Z. & Szczęśniak E., 2003, Czerwona lista roślin naczyniowych Dolnego Śląska [The red list of vascular plants of Lower Silesia], [in:] Z. Kącki (ed.), Zagrożone gatunki flory naczyniowej Dolnego Śląska [Endangered vascular plants of Lower Silesia], Instytut Biologii Roślin, Uniwersytet Wrocławski, Polskie Towarzystwo Przyjaciół Przyrody „Pro Natura”, Wrocław: 19-56.
- Kącki Z. & Michalska-Hejduk D., 2010, Assessment of biodiversity of *Molinia* meadows in Kampinoski National Parks based on biocenotic indicators, Polish Journal of Environmental Studies 19(2): 351-362.
- Kącki Z. & Załuski T., 2004, Zmiennowilgotne łąki trzęślicowe [*Selino-Molinietum* meadows], [in:] J. Herbich (ed.), Murawy, łąki, ziołorośla, wrzosowiska, zarośla. Poradniki ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny. Tom 3. [Grasslands, meadows, tall herb communities, heathlands, shrublands. Guide of habitats and species protection of Natura 2000 sites – methodical handbook], Ministerstwo Środowiska [the Ministry of Environment], Warszawa: 159-176.
- Kochanowska R., 1995, Łąki pełnikowe w dolinie Chocieli [*Trollius europaeus* meadows in the Chociel River valley], Chrony Przyrodę Ojczyzną 3: 37-43.

- Kochanowska R., 2005, Pełnik europejski, róża polskich łąk [The Globe flower, a rose of polish meadows], Oficyna In Plus, Szczecin.
- Kochanowska R. & Gamrat R., 2007, Zbiorowiska trawiaste z pełnikiem europejskim (*Trollius europaeus* L.) w dolinie Chocieli [Grass communities with Globe flower (*Trollius europaeus* L.) in the river Chociel Valley], Łąkarstwo w Polsce 10: 119-129.
- Kołodziejek J., 2012, Pełnik europejski *Trollius europaeus* L. [European Globe flower *Trollius europaeus* L.], [in:] R. Olaczek (ed.), Czerwona księga roślin województwa łódzkiego [The red date book of vascular plants of Łódzkie Voivodship], Ogród botaniczny w Łodzi, Uniwersytet Łódzki, Łódź: 204-205.
- Kołodziejek J. & Michalska-Hejduk D., 2004, Charakterystyka geobotaniczna łąk trzęślicowych *Molinietum caeruleae* na polanach śródleśnych północnej części województwa śląskiego [Geobotanic characteristic of the purple moor-grass meadow community *Molinietum caeruleae* on the clearings in the northern part of the Silesia Voivodeship], *Fragmenta Floristica et Geobotanica Polonica* 11: 141-155.
- Kondracki J., 2011, Geografia regionalna Polski [Regional geography of Poland], Wyd. Nauk. PWN, Warszawa.
- Kotańska M., 1993, Response of wet meadows of the *Calthion* alliance to variations of weather and management practices – a thirteen-year study of permanent plots, *Studia Naturae* 40: 1-47.
- Kostrakiewicz K., 2009, The influence of shadow created by adjacent plants on phenotypic plasticity of endangered species *Trollius europaeus* L. (Ranunculaceae), *Polish Journal of Ecology* 57(4): 625-634.
- Kostrakiewicz-Gierałt K., 2012, The impact of neighbourhood and gap character on seedling recruitment of *Trollius europaeus* L. and *Iris sibirica* L. in *Molinietum caeruleae* meadows, *Biodiversity Research and Conservation* 28: 37-44.
- Kucharczyk M. & Wójciak J., 1995, Ginące i zagrożone gatunki roślin naczyniowych Wyżyny Lubelskiej, Roztocza, Wołynia Zachodniego i Polesia Lubelskiego [Threatened vascular plants of the Lublin Upland, Roztocze, Western Volhynia and Polesie Lubelskie (Eastern Poland)], *Ochrona Przyrody* 52: 33-46.
- Kulik M., 2014, Changes of biodiversity and species composition of *Molinia* meadow depending on use method, *Polish Journal of Environmental Studies* 23(3): 773-782.
- Lemke T., Jansen A. & Porembski S., 2015, Multiple limitations to the persistence of *Trollius europaeus* in a fragmented agricultural landscape in the context of metapopulation theory, *Plant Ecology* 216: 319-330.
- Łuczaj Ł., 2011, Łąki w Komborni (PLH 180042) [Meadow in Kombornia PLH 180042], [in:] M. Rogala, A. Marcela (eds), *Obszary Natura 2000 na Podkarpaciu* [Natura 2000 site in Podkarpacie], Regionalna Dyrekcja Ochrony Środowiska, Rzeszów: 146-147.
- Łuczaj Ł. & Oklejewicz K., 2001, Supplement to the flora Jasło-Sanok Basin, *Fragmenta Floristica et Geobotanica Polonica* 8: 276-278.
- Matuszkiewicz W., 2008, Przewodnik do oznaczania zbiorowisk roślinnych Polski [Guide to identification of plant communities of Poland], Wyd. Nauk. PWN, Warszawa.
- Michalska-Hejduk D., 2001, Stan obecny i kierunki zmian roślinności nieleśnej Kampinoskiego Parku Narodowego [Current state and directions of change of non-forest vegetation of the Kampinos National Park], *Monographiae Botanicae* 89: 1-134.
- Michalska-Hejduk D. & Kopeć D., 2012, Dynamics of semi-natural vegetation with a focus of *Molinion* meadows after 50 years of strict protection, *Polish Journal of Environmental Studies* 21(6): 1731-1741.
- Mirek Z., Piękoś-Mirkowa H., Zajac A. & Zajac M., 2002, Flowering plants and pteridophytes of Poland – a checklist [Krytyczna lista roślin naczyniowych Polski], W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
- Muncaciu S., Gafta D., Cristea V., Rosca-Casian A. & Goia I., 2010, Eco-coenotic conditions and structure of *Trollius europaeus* L. populations in an extrazonal habitat complex (Transylvanian Carpathian Foothills). *Flora - Morphology, Distribution, Functional Ecology of Plants* 205(11): 711-720.
- Nowak A., Nowak S. & Spałek K., 2008, Red list of vascular plants of Opole Province, *Opole Scientific Society Nature Journal* 41: 141-158.
- Ochyra R., Żarnowiec J. & Bednarek-Ochyra H., 2003, Census catalogue of Polish Mosen, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
- Oklejewicz K., 1993, Flora Dołów Jasielsko-Sanockich [The flora of the Jasło-Sanok Basin], *Zeszyty Naukowe UJ, Prace Botaniczne* 26: 1-168.
- Oklejewicz K., 1996, Charakterystyka geobotaniczna Dołów Jasielsko-Sanockich [Geobotanical description of the Jasło-Sanok Basin], *Zeszyty Naukowe UJ, Prace Botaniczne* 27: 1-93.
- Parusel J. & Urbisz A., 2012, Czerwona lista roślin naczyniowych województwa śląskiego [The red list of vascular plants of Silesian Voivodship], *Raporty Opinie 6, Strategia ochrony przyrody województwa śląskiego do roku 2030. Raport o stanie przyrody województwa śląskiego. Czerwone listy wybranych grup grzybów i roślin województwa śląskiego* [Reports opinions 6, Conservation strategy of nature of the Silesian Voivodship. The red list of chosen groups of mushrooms and plants of Silesian Voivodship], Centrum Dziedzictwa Przyrody Górnego Śląska [Upper Silesian Nature Heritage Center], Katowice: 105-177.

- Piękoś-Mirkowa H. & Mirek Z., 2003, Atlas roślin chronionych. Flora Polska [Atlas of protected plants. Flora of Poland], Multico Oficyna Wydawnicza, Warszawa.
- Řezníčková M., 2007, Variability of the *Molinion* meadows in Slovakia, *Biologia*, Bratislava, Section Botany 62(6): 675-683.
- Rozporządzenie Ministra Środowiska z dnia 9.10.2014 r. o ochronie gatunkowej roślin (Dz.U. RP 2014, poz. 1409) [Regulation of the Minister of the Environment of 9 October 2014 on the species-specific protection of plants (Dz. U. RP [Journal of Laws RP] 2014, item 1409)], 2014, Kanc. Prezesa Rady Min., Warszawa.
- Sienkiewicz-Paderewska D., Borawka-Jarmułowicz B., Mastalerczuk G., Chodkiewicz A. & Stypiński P., 2012, Wpływ zaprzestania koszenia na roślinność łąki trzęślicowej (*Molinietum caeruleae*) [Effects of mowing cessation on *Molinietum caeruleae* meadow vegetation], *Woda-Środowisko-Obszary Wiejskie* 12, 1(37): 167-179.
- Suder A., 2007, Szata roślinna łąk wilgotnych (rzęd *Molinietalia caeruleae* W. Koch 1996) we wschodniej części Wyżyny Śląskiej [Vegetation of wet meadows (order *Molinietalia caeruleae* W. Koch 1996) in the eastern part of Silesia Upland], *Łąkarstwo w Polsce* 10: 159-172.
- Tomaszewska K., 2003, Zmiany w składzie gatunkowym fitocenoz na porzuconych łąkach pobagiennych [Changes in species composition of plant community on the abandoned drained meadows], *Annales Silesiae* 32: 103-116.
- Trąba C., 1997, Florystyczne zróżnicowanie zbiorowisk roślinności łąkowej rzędu *Molinietalia* w dorzeczu Łabuńki [Floristic differentiation of meadow plant communities from the order of *Molinietalia* in the Łabuńka River Basin], *Annales UMCS, Sectio E*, LII(23): 189-199.
- Trąba C. & Wolański P., 2012, Zróżnicowanie florystyczne zbiorowisk łąkowych ze związków *Molinion*, *Cnidion dubii* i *Filipendulion* w Polsce – zagrożenia i ochrona [Floristic diversity of meadows communities representing *Molinion*, *Cnidion dubii* and *Filipendulion* alliance in Poland – threats and protection], *Inżynieria Ekologiczna* 29: 224-235.
- Zajac A. & Zajac M., eds, 2001, Atlas rozmieszczenia roślin naczyniowych w Polsce [Distribution Atlas of Vascular Plants in Poland], Nakładem Pracowni Chorologii Komputerowej Instytutu Botaniki Uniwersytetu Jagiellońskiego [Edited by Laboratory of Computer Chorology, Institute of Botany, Jagiellonian University], Kraków.
- Zajac M. & Zajac A., 2009, The geographical element of native flora of Poland [Elementy geograficzne rodzimej flory Polski], Nakładem Pracowni Chorologii Komputerowej Instytutu Botaniki Uniwersytetu Jagiellońskiego [Edited by Laboratory of Computer Chorology, Institute of Botany, Jagiellonian University], Kraków.
- Zalewska J., 1997, Łąki trzęślicowe w dolinie Przemszy [The moor grass meadows in the Przemsza River Valley], *Ochrona Przyrody* 54: 73-79.
- Załuski T., 2007, Zagrożenia i ochrona zespołów trawiających [Threat and protection of grass communities], [in:] L. Frey (ed.), *Księga polskich traw* [The Book of Polish Grasses], Instytut Botaniki im. W. Szafera, Polska Akademia Nauk, Kraków: 283-316.
- Zarzycki K., Trzcńska-Tacik H., Różański W., Szelaż Z., Wołek J. & Korzeniak U., 2002, Ecological indicator values of vascular plants of Poland [Ekologiczne liczby wskaźnikowe roślin naczyniowych Polski], W. Szafer Institute of Botany, Polish Academy of Science, Kraków.
- Zelnik I., 2005, Meadows of the order *Molinietalia caerulea* Koch 1926 in south-eastern Slovenia, *Fitosocjologia* 42(1): 3-32.
- Żukowski W. & Jackowiak B., 1995, Ginące i zagrożone rośliny naczyniowe Pomorza Zachodniego i Wielkopolski [Endangered and threatened vascular plants of Western Pomerania and Wielkopolska], Bogucki Wyd. Naukowe, Poznań.