

The Twinflower (*Linnaea borealis* L.) in the northern part of the Południowopodlaska Lowland

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Abstract. *Linnaea borealis*, the twinflower, is considered a critically endangered species in the Południowopodlaska Lowland. The disappearance of the twinflower is mainly caused by habitat changes resulting from forest management, but also light deficiency due to the increase in canopy cover and growth of the shrub layer (processes of succession).

The aim of the paper is to present the actual distribution and phytosociological characteristics of *L. borealis* in the northern part of the Południowopodlaska Lowland. In this region, only three out of ten known areas of occurrence (Werchliś, Serpelice, Grala-Dąbrowizna) have endured to the present day. The twinflower occurs in pine forest, *Peucedano-Pinetum*, and mixed forest, *Quercus roboris-Pinetum*, communities.

A decrease in the ground cover of twinflower populations was observed in all existing twinflower locations. Although the area covered by the *Linnaea borealis* population in Werchliś increased tenfold during the last 20 years (from about 200 m² in 1993 to 1970 m² in 2013), its cover-abundance according to the Braun-Blanquet scale decreased from 5 to 3. The increase in the area covered by the twinflower population together with the accompanying decrease in cover-abundance is probably not a manifestation of species dynamics but rather a response to disadvantageous environmental changes (growth of canopy cover and shrub layer). Progressive light reduction can initiate the process of fragmentation of a population.

A decrease in the cover-abundance of the *L. borealis* population (from 4 to 2) was also observed in Serpelice. Its area was reduced to half of its original size due to anthropogenic destruction of this location. In the third region, Grala-Dąbrowizna, also the negative effects of competitive species (e.g. *Vaccinium myrtillus*, *V. vitis-idaea*) are considered.

Keywords: *Linnaea borealis*, distribution, phytosociology, Południowopodlaska Lowland

1. Introduction

The twinflower *Linnaea borealis* L. is a relict of the Late Glacial period. Czubiński (1950) classifies it as a subarctic boreal–mountain and continental element, whereas Meusel (1943) assigns it to the boreal and mountain species associated with the continental climate. The twinflower's range includes northern Europe, Asia and parts of North America. In Poland, it reaches the southern extent of its range. Zajac and Zajac (2001) list 233 twinflower stations in Poland, concentrated mainly in the northern part of the country and the Lublin region (Roztocze). In some sites, this species is considered a pseudo-relict (a relict species growing in new sites transformed by humans), which spreads by zoochory – its seeds are dispersed by birds (Czubiński 1950; Zaręba 1986; Browicz, Gostyńska-Jakuszczyńska 1966; Król 1977).

Linnaea borealis is a species characteristic of acidophilic forests of the *Vaccinio-Piceetea* class and – regionally – of the maritime *Empetro nigri-Pinetum* pine forests (Matuszkiewicz 2006). In central-eastern Poland, it is most often found in fresh pine forests (*Peucedano-Pinetum*, *Leucobryo-Pinetum*) and fresh mixed coniferous forests (*Pino-Quercetum*). According to Zieliński (1962), it also occurs in the Kozienicka Forest in typical hornbeam forests with a mixture of fir.

The twinflower is an endangered species in many regions of Poland, and thus strictly protected (Regulation of the Minister of the Environment 2012). It is considered extinct (category RE) in the Opole Voivodeship (Nowak et al. 2008), northern part of the Silesian-Cracow Upland (Hereźniak 2002) and Lower Silesia (Kącki et al. 2003). It is critically endangered (CR) in the Południowopodlaska Lowland (Głowacki et al. 2003), Wielkopolska region (Jackowiak et al. 2007) and the Polish Carpathians (Pię-

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koś-Mirkowa H. 2008). It is dying out in the Świętokrzyskie region (Broz 1990) and is threatened with extinction (EN) in the Lublin region (Kucharczyk, Wójciak 1995). Since 2005, the Department of Botany at Siedlce University of Natural Sciences and Humanities has been monitoring the twinflower and a small group of protected, endangered species (such as *Cypripedium calceolus*, *Adenophora liliifolia*, *Liparis loeselii*).

During studies of the flora in the vicinity of Siedlce, a new stand of twinflower was found near Grala-Dąbrowizna in the Skórzec Township, in private forests overseen by the Siedlce Forest Inspectorate, district 10 Grala-Dąbrowizna.

The aim of this study is to present the current distribution and phytosociological characteristics of existing stations of *L. borealis* in the northern part of the Południowopodlaska Lowland.

2. Study area and methodology

The study was conducted in the Mazowsze-Podlasie Region (Trampller et al. 1990), in the mesoregions of the Siedlecka Upland, Podlasie Bug River Gorge, the Węgrówskie Depression, Łukowska Plain and Kałuszyńska Upland. They form a slightly undulating upland with altitudes ranging from 150 to 200 m above sea level. The terrain is dotted with the inselbergs of moraine hills, kames and eskers formed during the Warthe sub-stage of the Ice Age (Kondracki 2013). The climate has a mean annual temperature of about 7.0°C (1°C lower than in areas further to the west) and an annual rainfall of about 550 mm. Field research was conducted in 2013 to verify the stations reported in

the literature. An exploration of potential floral habitat sites of the species in neighbouring areas was also carried out.

A single phytosociological relevé was taken according to the generally accepted Braun-Blanquet method (Braun-Blanquet 1964) of those stations where the presence of *L. borealis* was confirmed. The area of the relevé was 100–400 m² depending on the size of the plot. The cover-abundance of each plant layer and their species composition were noted. Species were classified according to phytosociological units, allowing us to specify the phytosociological characteristics of the stations. The area covered by the population was also estimated. Data on the surface area and species composition of the station were compared with the literature from about 20 years ago.

New stations of *L. borealis* in Grala-Dąbrowizna were mapped at a scale of 1:50. Each species of tree, the range of competing species (bilberry and lingonberry) and patches of light were noted. The nomenclature used of vascular plant species is from Mirek et al. (2002), mosses from Ochrya et al. (2003) and their phytosociological affiliation was determined according to Matuszkiewicz (2005).

3. Results

The presence of *L. borealis* was confirmed in three of ten known sites of the Południowopodlaska Lowland, near the settlements of Grala-Dąbrowizna, Serpelice and Werchliś (Fig. 1). The general characteristics of the twinflower stations are presented in Table 1.

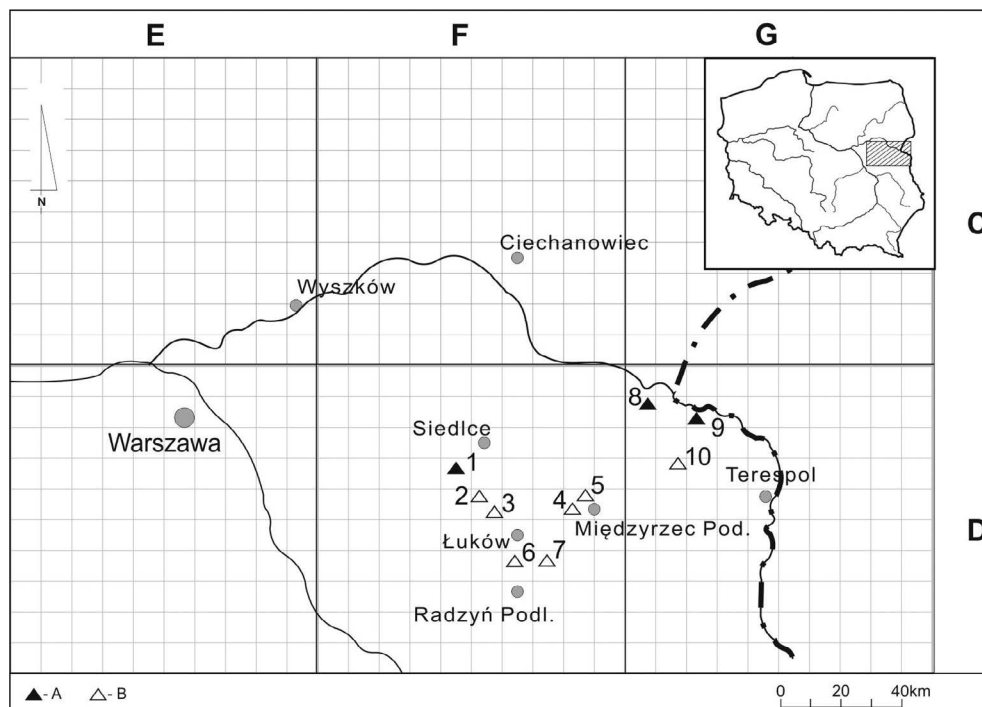


Figure 1. Distribution of *Linnaea borealis* stations in the northern part of the Południowopodlaska Lowland mapped on ATPOL grid squares (10 x 10 km, according to Zając A., Zając M. 2001). A – existing stations, B – stations where *L. borealis* was not confirmed. 1 – Grala-Dąbrowizna, 2 – Domanice, 3 – Klimki, 4 – Jelnica, 5 – Międzyrzec Podlaski, 6 – Ciężkie, 7 – Bedlne, 8 – Serpelice, 9 – Werchliś, 10 – Hrud.

Table 1. General characteristics of *Linnaea borealis* stations in the Południowopodlaska Lowland

No. of stand	Forest district	Locality	ATPOL square	Area (m ²) 2013	Community	Source of information
1	Siedlce	Graża- Dąbrowizna	FD34	120	<i>Peucedano-Pinetum</i>	leg. Sikorski 2013
2	Łuków	Klimki	FD45	not confirmed	lack of data	leg. Fijałkowski 1973
3	Łuków	Domanice	FD45	not confirmed	<i>Quercus roboris-Pinetum</i>	Sokołowski 1961
4	Międzyrzec Podlaski	Jelnica	FD48	not confirmed	lack of data	leg. Fijałkowski 1968
5	Międzyrzec Podlaski	Międzyrzec Podlaski	FD48	not confirmed	lack of data	Eichler 1883
6	Łuków	Ciężkie gm. Wojcieszków	FD66	not confirmed	lack of data	leg. Fijałkowski 1967
7	Radzyń Podlaski	Bedlne	FD67	not confirmed	lack of data	leg. Fijałkowski 1975
8	Sarnaki	Serpelice	GD10	91,4	<i>Peucedano-Pinetum</i>	Ciosek 1998
9	Biała Podlaska	Werchliś	GD12	1970	<i>Quercus roboris-Pinetum</i>	Marciniuk, Wierzba 1996
10	Biała Podlaska	Hrud	GD31	not confirmed	<i>Peucedano-Pinetum</i>	leg. Fijałkowski 1962; potw. Ciosek 1998

Despite years of searching, we did not find twinflower stands in the areas of Międzyrzec Podlaski (Eichler 1883 leg. Fijałkowski 1968) or in the Łuków Forest District (Sokołowski 1961 leg. Fijałkowski 1973). It has probably also disappeared from Hrud and the Biała Podlaska State Forest Inspectorate (leg. Fijałkowski 1962), confirmed by Ciosek (1998). In 2005, over a dozen twinflower shoots were observed, but this species was not found again in 2013. No stations of this species were found in the vicinity of Bedlne village near Radzyń Podlaski (leg. Fijałkowski 1975) or in Ciężkie in the Wojcieszków Township (leg. Fijałkowski 1967).

The largest area (1970 m²) of *L. borealis* was found near the village of Werchliś. This stand is located to the north of the village (52°11'44.70"N, 23°17'13.93"E), in ATPOL square GD12, not GD22 – as shown in the atlas of the distribution of plants (Zajac, Zajac 2001). The sparsely canopied tree stand (a₁ – 40%, a₂ – 20%) is made up of *Pinus sylvestris* and *Quercus robur* (Tab. 2). The shrub layer, with a cover of 50%, is dominated by *Q. robur* with a mix of *Betula pendula*, *Sorbus aucuparia*, *Padus avium*, *P. serotina* and *Corylus avellana*. The herb layer is dominated by *L. borealis* (cover 3), *Festuca ovina*, *Luzula pilosa* and *Vaccinium myrtillus* (cover 1). Fragments of the station were covered by dense patches of stiff clubmoss (*Lycopodium annotinum*), sidebells wintergreen (*Orthilia secunda*) and blackberry (*Rubus* sp.). The layer of moss is dominated by *Pleurozium schreberii* and *Hylocomium splendens*. In total, 26 species of plants were recorded in the relevé. The presence of oak in all layers of the community, as well as bird cherry and hazel in the shrub layer indicates the relatively high fertility of

the soil, qualifying the described forest fragment as continental mixed forest habitat *Quercus roboris-Pinetum*.

This station experienced the greatest change due to the process of natural succession. The tree and shrub canopy increased from 40 to 50%; individual blackberry *Rubus* sp. (cover 2) plants are also beginning to shade the twinflower stands. Dense patches of stiff clubmoss *L. annotinum* and bilberry *V. myrtillus* were noted here for the first time. Both are species which may compete with twinflower stands.

The plots of twinflower were significantly smaller near Graża-Dąbrowizna – 120 m² and Serpelice – 91.4 m².

The station near Graża-Dąbrowizna (52°05'17.61"N, 22°06'53.31"E) is located in a fresh coniferous forest, whose tree stand has canopy layers of 40% for a₁ and 20% for a₂. The a₁ layer is comprised of *P. sylvestris*, while a₂ includes *P. sylvestris* and *Q. robur*. The shrub layer with a cover of 40% is made up of *Q. robur* (covering 3), with a small number of *Frangula alnus* and *Juniperus communis*. *L. borealis* dominated the groundcover (cover 5). A significant proportion of layer c cover was made up of such species as *V. myrtillus* (cover 3), *V. vitis-idaea* (2) and *Melampyrum pratense* (1). There were no species characteristic for lower phytosociological units, but several characteristic and distinctive species of the *Peucedano-Pinetum* community were noted in close proximity (*Peucedanum oreoselinum*, *Solidago virgaurea*, *Polygonatum odoratum*). Accordingly, the described portion of the forest complex qualified for this classification. The moss layer (30% cover) was dominated by *P. schreberii* and *H. splendens*. In total, 22 species of plants were recorded in the relevé.

Table 2. Phytosociological characteristic of *Linnaea borealis* stations in the Południowopodlaska Lowland (data from 1993 and 1996 according to the authors)

Locality		Grala-Dąbrowizna	Serpelice		Werchliś	
Date		14.06.2013	24.05.96	10.07.2013	09.1993	10.07.2013
Area of plot m ²		ca.120	ca. 200	91,4	ca. 200	1970
Cover of layer a (%)		30	60	50	40	50
Cover of layer a ₁ (%)		30	30	50	40	40
Cover of layer a ₂ (%)		10	40	20	-	20
Cover of layer b (%)		40	50	50	40	50
Cover of layer c (%)		90	80	70	100	70
Cover of layer d (%)		30	100	60	40	60
Area of relevé (m ²)		100	100	100	100	400
Number of species		22	34	34	13	26
Trees and shrubs						
<i>Pinus sylvestris</i>	a ₁	2	3	3	3	3
<i>Pinus sylvestris</i>	a ₂	1	2	2		1
<i>Pinus sylvestris</i>	b		1		1	
<i>Pinus sylvestris</i>	c	+	+			
<i>Quercus robur</i>	a ₂	1	1	2		2
<i>Quercus robur</i>	b	3	2	2	2	3
<i>Quercus robur</i>	c	2	+	1	+	+
<i>Betula pendula</i>	a ₂		1	1		
<i>Betula pendula</i>	b			2		1
<i>Betula pendula</i>	c	+				
<i>Populus tremula</i>	a ₂		1	+		
<i>Populus tremula</i>	b		1	+		
<i>Populus tremula</i>	c		+	+	+	1
<i>Juniperus communis</i>	b	1	2	1		1
<i>Juniperus communis</i>	c		1	1		1
<i>Frangula alnus</i>	b	1				
<i>Frangula alnus</i>	c	1	+	+		
<i>Malus sylvestris</i>	b		1			
<i>Malus sylvestris</i>	c		+	+		
<i>Sorbus aucuparia</i>	b			1	1	1
<i>Sorbus aucuparia</i>	c		+	+		+
<i>Euonymus verrucosus</i>	b		1	1		
<i>Salix caprea</i>	b		1			
<i>Padus avium</i>	b			2		1
<i>Padus serotina</i>	b					1
<i>Corylus avellana</i>	b					1
Ch. D. Vaccinio-Piceetea						
<i>Linnaea borealis</i>	c	5	4	2	5	3
<i>Hylocomium splendens</i>	d	2	4	2	2	2
<i>Pleurozium schreberii</i>	d	2	4	3	2	3
<i>Vaccinium myrtillus</i>	c	3	3	2		1

Locality		Grala-Dąbrowizna	Serpelice		Werchliś	
Date		14.06.2013	24.05.96	10.07.2013	09.1993	10.07.2013
<i>Orthilia secunda</i>	c		1	2	1	2
<i>Vaccinium vitis-idaea</i>	c	2	2	1		
<i>Melampyrum pratense</i>	c	1	1	1		
<i>Trientalis europaea</i>	c	r	1	1		
<i>Rubus saxatilis</i>	c	+	r	+		
<i>Luzula pilosa</i>	c	+		1		2
<i>Solidago virgaurea</i>	c		+	+		+
<i>Dicranum undulatum</i>	d		1	1		
<i>Chamaecytisus ratisbonensis</i>	c		1	+		
<i>Chimaphila umbellata</i>	c		+	1		
<i>Moneses uniflora</i>	c		+	(r)		
<i>Lycopodium annotinum</i>	c					3
Accompanying species						
<i>Festuca ovina</i>	c	+	+	2	3	3
<i>Anthoxanthum odoratum</i>	c	+	1	+	+	+
<i>Hieracium murorum</i>	c		r	+	+	+
<i>Veronica chamaedrys</i>	c	+	+	1		
<i>Deschampsia flexuosa</i>	c		+	+		+
<i>Dryopteris carthusiana</i>	c		r	1		+
<i>Agrostis capillaris</i>	c	+	+			
<i>Fragaria vesca</i>	c		1	1		
<i>Viola canina</i>	c		r	+		
<i>Polytrichum juniperinum</i>	d				1	1
<i>Hieracium lachenalii</i>	c				+	+
<i>Carex ericetorum</i>	c	+				
<i>Hieracium pilosella</i>	c	+				
<i>Rumex acetosa</i>	c	+				
<i>Hypochoeris radicata</i>	c	r				
<i>Polytrichum commune</i>	d		1			
<i>Knautia arvensis</i>	c			1		
<i>Rubus sp.</i>	c					2
<i>Conyza canadensis</i>	c					r

The station near Serpelice (52°17'12.47"N, 23°02'43.90"E) is located in the *Peucedano-Pinetum* fresh pine forest. The tree stand of 50% a₁ layer cover is made up of *P. sylvestris* (cover 3), while *Q. robur*, *P. sylvestris* and *B. pendula* comprise layer a₂. The shrub layer with a canopy of 50% is dominated by *Q. robur*, *P. avium* and *B. pendula* (cover 2), with a lesser proportion of *J. communis*, *S. aucuparia* and *Euonymus verrucosus*. In addition to *L. borealis* (cover 2), the following species had the highest proportion of cover: *Vaccinium myrtillus*, *V. vitis-idaea*, *Orthilia secunda*, *Festuca ovina*, *Melampyrum pratense* and *Luzula pilosa*. Also present were a number

of species characterising and distinguishing the *Peucedano-Pinetum* community: umbellate wintergreen *Chimaphila umbellata* and goldenrod *S. virgaurea*, while *Peucedanum oreoselinum* and scented Solomon's seal *P. odoratum* also were in close proximity to the plot. The moss layer, at 60% cover, was dominated by *Pleurozium schreberii* and *Hylocomium splendens*. In total, 34 plant species were recorded in the relevé.

All three described stations were adjacent to rarely used forest roads. The twinflower was blooming at each station and no fruiting specimens were found.

In Grala-Dąbrowizna, the twinflower fully covered the plot (90–100% coverage) in sunny areas (light squares on the map). Coverage was significantly lower in shady areas (40–60% of cover). Competitive groundcover species, such as *V. myrtillus* and *V. vitis-idaea*, may adversely affect the twinflower population. Confirmation of such interactions between the species, however, would be possible only after conducting long-term population studies.

4. Discussion

Only three of the 10 *L. borealis* stations reported for the Południowopodlaska Lowland remain today. We were unable to confirm the stations in the vicinity of Biała Podlaska, Międzyrzec Podlaski, Łuków, Wojcieszków and Radzyń Podlaski. The population directly north of the study area (the right bank of the Bug River Valley) is also dying out, as the forest was clear-cut at the station in Wyszków (Czarnota 1973). A few specimens were confirmed there in 1990, but in 1992, the species was not found. In the Białowieża

Forest, Sokołowski (1995) found only one twinflower station of three previously reported ones. Confirmation is also required of an unpublished station in Pobikry (*leg.* Głowacki 1993). In central Poland (Łódź Voivodeship), the species has survived in six locations out of ten reported earlier (Jakubowska-Gabara, Kurowski 2012).

Existing stations of twinflower are located in fresh pine forests (*Peucedano-Pinetum*) and continental mixed forests (*Quercus roboris-Pinetum*), communities with the typical habitats where the species is found (Matuszkiewicz 2008; Piękoś-Mirkowa, Mirek 2003).

Over the last 20 years, the size of the area populated by *L. borealis* near the village of Werchliś increased tenfold, from about 200 m² in 1993 (Marciniuk, Wierzba 1996) to 1970 m² in 2013. It is now one of the largest stations in Poland. Even in the centre of the species' range (Nidzica Forest), none of its plots exceeds 900 m² (Środa, Dabrowski 1999).

The reason for the disappearance of twinflower stations is primarily habitat change associated with forest management and succession. One of the most important environmental

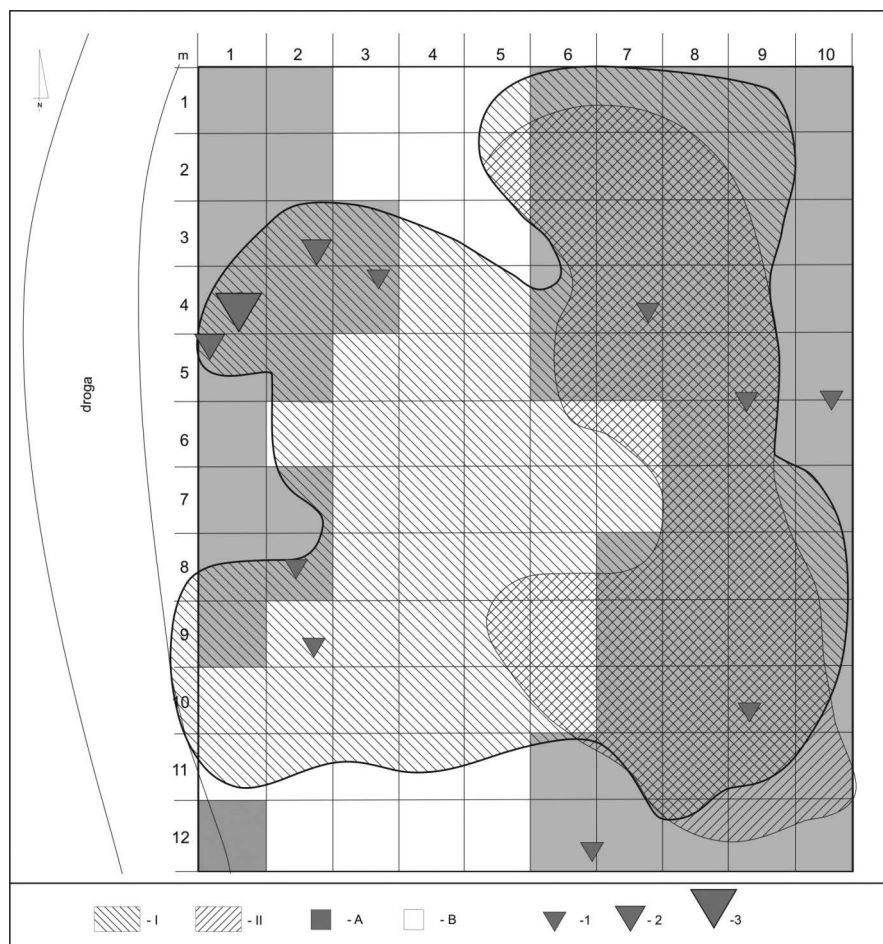


Figure 2. Cartogram of *Linnaea borealis* station in Grala-Dąbrowizna. I – *Linnaea borealis*, II – *Vaccinium myrtillus* and *Vaccinium vitis-idaea*; 1 – tree of diameter < 20 cm, 2 – tree of diameter 21–40 cm, tree of diameter 41–60 cm; A – shaded area, B – sunny area

factors affecting the condition of the *L. borealis* population is the availability of light (Browicz, Gostyńska-Jakuszczyńska 1966; Głazek 1969; Niva 2003; Worrell, Dunlop 2003; Niva et al. 2006). Numerous studies (Traczyk 1967; Głazek 1969; Izdebski et al. 1988; Lorens 1993) indicate that twinflower grows in the direction of moderate sunlight, but not in full sun. For this reason, many stations of this species are found near roads or tract boundaries. The twinflower avoids shady areas. Izdebski et al. (1988) and Jakubowska-Gabara and Kurowski (2012) reported on the adverse effect of shrubs on the twinflower. When light conditions are inferior, the cover breaks up, which causes the station to fragment and small enclaves are formed. Fijałkowski (1994) writes that the end result of these changes may be the disappearance of the station. In the last 20 years at Werchliś, the amount of light reaching the forest floor is diminishing due to an increase in the density of the tree and shrub canopy layers. Although the station has not yet become fragmented, twinflower cover at this site has decreased from 5 to 3, which may be the beginning of this process. The population is spreading to the south, where there are better light conditions (existence of a forest road).

Piękoś-Mirkowa and Mirek (2003) argue that the variations in the size of twinflower stations can also be associated with a periodic or permanent variability of habitat conditions, suggesting that in dry years, twinflower population size decreases, and during wet years, it clearly grows. This is refuted by the results of Głazka (1969), Traczyk (1967) and Król (1977), which indicate that dry and wet years do not affect the condition of the twinflower and the size of its stations.

The black cherry *P. serotina*, a highly expansive species, was noted at the station in Werchliś. It is a potential threat to the twinflower station. It quickly overtakes the understory and lower layers of the tree stand, making natural forest regeneration more difficult and eliminating groundcover species (Dajdok et al. 2007; Tokarska-Guzik et al. 2012).

The Serpelice station decreased in size from approximately 200 m² in 1996 to 91.4 m² in 2013. There is a large erratic boulder in the eastern part of the station, where formerly twinflower had grown all around it. Currently, there is no twinflower on its eastern side. This is probably due to rock mining activities. A decrease in twinflower cover (from 4 to 2) was also observed in the rest of the station. Because the light conditions here are stable, this change is probably due to anthropogenic causes.

In the sunlit areas of Grala-Dąbrowizna, twinflower was abundant (cover 5). The proportion of this species in the groundcover was smaller in shadier places. We can assume that competitive undergrowth species, such as *V. myrtillus* and *V. vitis-idaea*, limit the twinflower population. It would be useful to methodically study this problem.

Twinflower blooms at all of the stations. No fruiting was observed, which rarely occurs in Poland. Fruiting specimens

were found by Stecki and Przybylski (1957) and Biernacki (1962) in the Wielkopolski National Park.

Together with the Siedlce Forest Inspectorate, efforts are being made to protect the new station in Grala-Dąbrowizna as a natural monument. To this day, in spite of repeated reminders, the Serpelice station lacks formal protection. All existing *L. borealis* stations are being monitored (biometric and habitat studies).

5. Conclusions

Based on the research findings, the following conclusions can be made:

1. The number of existing *L. borealis* stations in the Południowopodlaska Lowland is decreasing. Only three of ten known stations of this species have survived in the northern part of the Południowopodlaska Lowland to this day.

2. The cover of the twinflower population is decreasing at confirmed historical stands. At Werchliś, this is most likely due to deteriorating light conditions, while at Grala-Dąbrowizna, to competition from such species as *V. myrtillus* or *V. vitis-idaea*.

3. An increase in the area occupied by the twinflower seems to be rather a response to unfavourable environmental conditions than a growth trend in the size of the population. At the station near the village of Werchliś, where the population increased in size by almost tenfold over the last 20 years (it is considered the largest in Poland today), its cover-abundance has simultaneously decreased. This is probably the result of deteriorating light conditions and may be the beginning of the fragmentation of this stand.

Conflict of interest

The authors declare that there is no potential conflict of interest.

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References

- Biernacki A. 1962. Nowe stanowisko zimoziołu północnego *Linnaea borealis* L. w południowej Wielkopolsce. *Przyroda Polski Zachodniej* 6: 67–70.
- Braun-Blanquet J. 1964. *Pflanzensoziologie. Grundzüge der Vegetationskunde*. Wien-New York, Springer Verlag.

- Browicz K., Gostyńska-Jakuszczyńska M. 1966. *Linnaea borealis* L., in: Atlas rozmieszczenia drzew i krzewów w Polsce, 5 (eds. S. Białobok, Z. Czubiński). Warszawa, PAN, Zakład Dendrologii i Arboretum Kórnickie, p. 21–24.
- Bróz E. 1990. Lista wymierających i zagrożonych gatunków roślin naczyniowych Krainy Świętokrzyskiej. *Rocznik Świętokrzyski* 17: 97–105.
- Ciosek M. 1998. Zimozioł północny *Linnaea borealis* na terenie Parku Krajobrazowego Podlaski Przełom Bugu. *Chrońmy Przyrodę Ojczyznę* 54(6): 112–114.
- Czarnota K. 1973. Stanowisko zimoziołu północnego *Linnaea borealis* i barwinka pospolitego *Vinca minor* w Puszczy Białej na Mazowszu. *Chrońmy Przyrodę Ojczyznę* 29(2): 69–70.
- Czubiński Z. 1950. Z zagadnień geobotanicznych Pomorza Zachodniego. *Badania Fizjograficzne nad Polską Zachodnią* 2(4): 439–658.
- Dajdok Z., Krzysztofiak A., Krzysztofiak L., Romański M., Śliwiński M. 2007. Rośliny inwazyjne w Wigierskim Parku Narodowym. Krzywe, Wigierski Park Narodowy. <http://www.wigry.win.pl/inwazyjneWPN.pdf>
- Eichler B. 1883. Spis roślin jawnopłciowych rosnących w okolicach Międzyrzecza położonego w guberni Siedleckiej, w powiecie Radzyńskim. *Pamiętnik Fizyograficzny* 3: 318–329.
- Fijałkowski D. 1994. Flora roślin naczyniowych Lubelszczyzny, t. 1 i 2. Lublin, Lubelskie Towarzystwo Naukowe. ISBN 83-85491-45-7, 83-84191-48-1.
- Głazek T. 1969. Ekologiczna charakterystyka stanowisk *Linnaea borealis* L. w lasach Nadleśnictwa Ćmielów (Przygórze Hłżeckie). *Fragmenta Floristica et Geobotanica* 15(3): 333–343.
- Głowacki Z., Falkowski M., Krechowski J., Marciniuk J., Marciniuk P., Nowicka-Falkowska K., Wierzba M. 2003. Czerwona lista roślin naczyniowych Niziny Południowopodlaskiej [The red list of vascular plant of the Południowopodlaska Lowland]. *Chrońmy Przyrodę Ojczyznę* 59(1): 5–41.
- Hereźniak J. 2002. Regionalna lista wymarłych i zagrożonych gatunków roślin naczyniowych północnej części Wyżyny Śląsko-Krakowskiej. *Acta Universitatis Lodzianensis, Folia Biologica et Oecologica* 1: 39–63.
- Izdebski K., Lipiec W., Lorens B., Popiołek Z. 1988. Ekologiczna ocena stanowisk *Linnaea borealis* L. w Roztoczańskim Parku Narodowym. *Annales UMCS, Ser. C* 43(11): 147–160.
- 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., Kurowski J.K. 2012. *Linnaea borealis* L., in: Czerwona księga roślin województwa łódzkiego. Zagrożone rośliny naczyniowe. Zagrożone zbiorowiska roślinne (ed. R. Olaczek). Łódź, Ogród Botaniczny w Łodzi, Uniwersytet Łódzki, s. 128–129. ISBN 978-83-920604-4-4.
- Kącki Z., Dajdok Z., Szczęśniak E. 2003. Czerwona lista roślin naczyniowych Dolnego Śląska, in: Zagrożone gatunki flory naczyniowej Dolnego Śląska (ed. Z. Kącki). Wrocław, Instytut Biologii Roślin Uniwersytetu Wrocławskiego, PTPP „pro Natura”, p. 19–56. ISBN 8391962601.
- Kondracki J. 2013. Geografia regionalna Polski, Warszawa, PWN. ISBN 9788301160227.
- Król S. 1977. Zimozioł północny (*Linnaea borealis* L.) na nowym stanowisku koło Opatowa w powiecie kępińskim. *Roczniki Dendrologiczne*, 30: 75–82.
- Kucharczyk M., Wójciak J. 1995. Ginące i zagrożone gatunki roślin naczyniowych Wyżyny Lubelskiej, Roztocza, Wołyń Zachodniego i Polesia Lubelskiego. *Ochrona Przyrody* 52: 33–46.
- Lorens B. 1993. Nowe stanowisko zimoziołu północnego *Linnaea borealis* L. w Roztoczańskim Parku Narodowym. *Parki Narodowe i Rezerwaty Przyrody* 12(1): 49–54.
- Marciniuk P., Wierzba M. 1996. Nowe stanowisko *Linnaea borealis* (*Caprifoliaceae*) w województwie białkopodlaskim na tle występowania gatunku w centralnej i wschodniej części Nizin Środkowopolskich. *Fragmenta Floristica et Geobotanica, Ser. Polonica*, 3: 99–102.
- Matuszkiewicz J. M. 2005. Przewodnik do oznaczania zbiorowisk roślinnych Polski, Warszawa, PWN. ISBN 83-01-14439-4.
- Meusel H. 1943. Vergleichende Arealkunde. Berlin.
- Mirek Z., Piękoś-Mirkowa H., Zajac A., Zajac M. 2002. Flowering plants and pteridophytes of Poland – a checklist, Biodiversity of Poland, 1, Kraków, W. Szafer Institute of Botany, Polish Academy of Sciences, 442 p. ISBN 83-85444-83-1.
- Niva M. 2003. Life history strategies in *Linnaea borealis*. Acta Universitatis Upsalensis, Uppsala University, Uppsala. ISBN 91-554-5754-1.
- Niva M., Svensson B. M., Karlsson P. S. 2006. Effects of light and water availability on shoot dynamics of the stoloniferous plant *Linnaea borealis*. *Ecoscience* 13(3): 318–323.
- 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 mosses. Katalog mchów Polski. Biodiversity of Poland, 3. Kraków, W. Szafer Institute of Botany, Polish Academy of Sciences. ISBN 83-85444-84-X.
- Piękoś-Mirkowa H., Mirek Z. 2003. Flora Polski. Atlas roślin chronionych. Multico Oficyna Wydawnicza, Warszawa. ISBN 83-7073-256-9.
- Piękoś-Mirkowa H. 2008. Zimozioł (*Linnaea*) północny, in: Czerwona Księga Karpat Polskich. Rośliny naczyniowe [Red data book of the Polish Carpathians. Vascular Plants] (eds. Z. Mirek, H. Piękoś-Mirkowa). Kraków, Instytut Botaniki im. W. Szafera, PAN, p. 294–295. ISBN 978-83-89648-71-6.
- Rozporządzenie Ministra Środowiska z dnia 5 stycznia 2012 r. w sprawie ochrony gatunkowej roślin. Dz.U. 2012 nr 0 poz. 81.
- Sokołowski A. 1961. Nowe stanowisko zimoziołu północnego na Płaskowzgórzu Łukowsko-Siedleckim. *Chrońmy Przyrodę Ojczyznę* 17(2): 44.
- Sokołowski A.W. 1995. Flora roślin naczyniowych Puszczy Białowieskiej. Białowieża, Białowieża, Białowieża Park Narodowy. ISBN 83-90-265-125.
- Stecki K., Przybylski T. 1957. Zimozioł północny (*Linnaea borealis* L.) i inne rzadsze rośliny w Wielkopolsce. *Przyroda Polski Zachodniej* 4(1-4): 65–76.
- Środa M., Dąbrowski S. 1999. Stanowisko zimoziołu północnego *Linnaea borealis* w Puszczy Nidzickiej. *Chrońmy Przyrodę Ojczyznę* 55(3): 108–111.

- Tokarska-Guzik B., Dajdok Z., Zając M., Zając A., Urbisz A., Danielewicz W., Hołdyński C. 2012. Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem roślin inwazyjnych. Warszawa, GDOŚ. ISBN: 978-83-62940-34-9.
- Traczyk H. 1967. *Linnaea borealis* L. i *Botrychium multifidum* (Gm.) Rupr. w Puszczy Kampinoskiej. *Fragmenta Floristica et Geobotanica* 13(3): 319–321.
- Trampler T., Kliczkowska A., Dmytreko E., Sierpińska A. 1990. Regionalizacja przyrodniczo-leśna na podstawach ekologiczno-fizjograficznych. Warszawa, Państwowe Wydawnictwo Rolnicze i Leśne.
- Worrell R., Dunlop B. 2003. The influence of past management of pinewoods on the occurrence of twinflower. Stirling, Plantlife Scotland.
- Zając A., Zając M. (ed.) 2001. Atlas rozmieszczenia roślin naczyniowych w Polsce. Kraków, Pracownia Chorologii Komputerowej Instytutu Botaniki Uniwersytetu Jagiellońskiego. ISBN 8391516113.
- Zaręba R. 1986. Lokalne migracje zimoziołu północnego *Linnaea borealis* L. w nadleśnictwie Rogów i jego ochrona w lasach gospodarczych i w rezerwacie „Górki”. *Acta Universitatis Lodziensis, Folia Zoologica*, 3: 193–197.
- Zieliński T. 1962. Stanowisko zimoziołu północnego w Puszczy Kozienickiej. *Chrońmy Przyrodę Ojczyzn*, 18(1): 34–36.

Author's contribution

M. T. C., J. K. and K. P. – concept and assumptions of research, preparation of the text of manuscript, interpretation of results, review of the literature, fieldworks; R. S. and A. T. – fieldworks, preparation of figures.