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Threatened, protected, and rare species of vascular plants in spring complexes in the central part of Polish Pomerania

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Abstract: Within 46 individually researched spring complexes in the central part of Polish Pomerania, the presence of 101 protected, threatened, and rare species was noted. Of these species, 75 were directly linked with underground water outflow. The number of species involved in various habitats ranged from 8 to 33, as 8 were recorded in spring communities, 10 in rush and sedge communities, 33 in mesotrophic rich fens, 28 in meadows and tall forb communities, 12 in alder woods, 18 in alder-ash woods, and 28 in beech woods and oak-hornbeam woods. The flora of the studied spring ecosystems includes 49 protected species, 41 of which are strictly and 8 partly protected in Poland. Particular care and attention should be directed to the 65 species that are endangered or vulnerable. Among them, 3 are endangered on the European scale: *Cypripedium calceolus, Hammarbya paludosa* and *Saxifraga hirculus*.

Key words: endangered species, threatened species, protected species, springs, mires, spring ecosystem, Pomerania, Poland

1. Introduction

Spring ecosystems in Pomerania are most often situated in valleys of small rivers fed by underground water supplies. They often form a complex spatial system composed of springs and the associated mires and other communities.

In the Pomeranian landscape, spring ecosystems cover relatively small areas but their role in maintaining biological diversity is very large. They are home to countless species of both plants and animals, many of which are protected or threatened by extinction. The exceptional floristic value of spring ecosystems was described in numerous publications from the Gdańsk Pomerania (Herbich & Stasiak 1971; Herbich 1982, 1994, 1998; Herbich & Górski 1993; Herbichowa & Herbich 1998) as well as from other parts of Polish Pomerania (Jasnowski *et. al.* 1986; Osadowski & Wołejko 1997; Osadowski 1999, 2000). Of particular interest is the work by Wołejko (2000), which presents evidence of the presence of protected and endangered species in spring complexes of northwestern Poland.

This study aims to supplement the published data on spring complexes in the central part of Polish Pomerania and on rare, threatened and protected vascular plant species found there.

2. Material and methods

For the analysis of threatened, rare and protected species within spring ecosystems, personally collected data from the banks of the rivers Chociel, Radew, Stropna, Wieprza and Studnica were used; these were published in the years 1997-2002 (Osadowski & Wołejko 1997; Osadowski *et al.* 1998, 2000; Osadowski 2002). Unpublished data collected in 2002-2005 within spring complexes of the Parsęta, Wieprza, Grabowa, Słupia, and Łupawa rivers were also utilized. Collectively, 34 spring complexes were studied; their locations are mapped in Fig. 1.

The term 'spring complexes' was adopted from Wołejko's (1996) work. According to his definition, a spring complex can be divided into two parts: one characterized by erosion, and the other by accumulation. Components of the former include the spring and its outflow, as well as the eroded slopes of the spring niche. The other part consists of spring mires and percolating

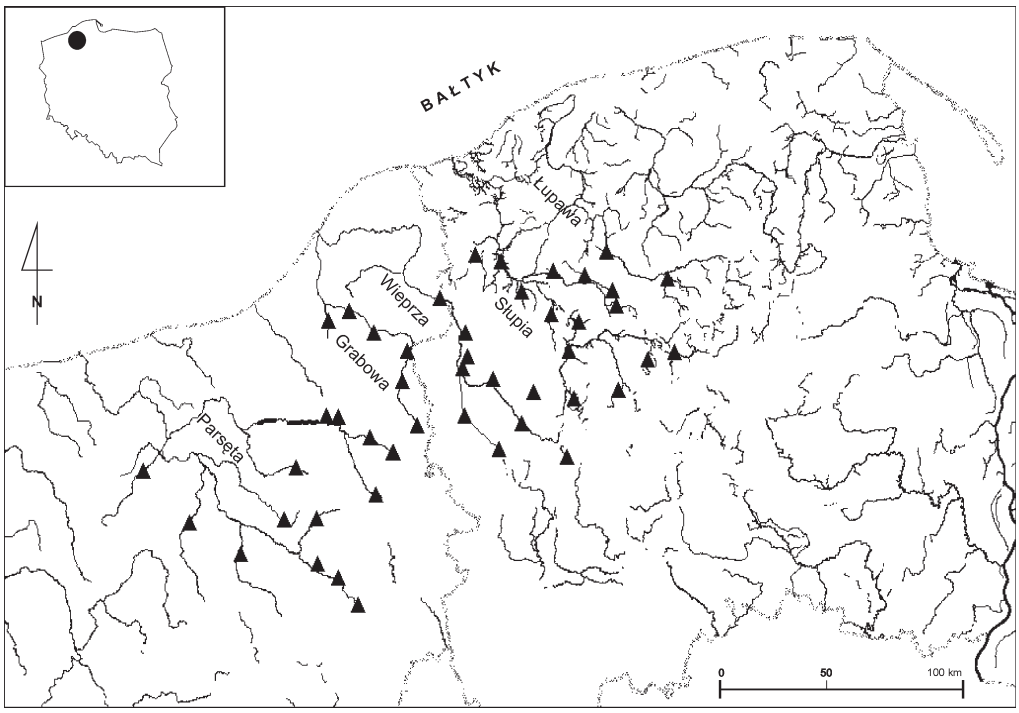

Fig. 1. Distribution of studied spring complexes in the area of the Upper Parsęta, Wieprza, Grabowa, Słupia, and Łupawa catchments

mires, being mainly fens, i.e. soligenous mires (see also Dembek 1992).

Seven types of habitats were identified in the studied spring complexes: (1) springs and their outflows, (2) rush and sedge communities, (3) mesotrophic rich fens, (4) meadows and tall forb communities, (5) alder woods, (6) alder-ash woods, and (7) oak-hornbeam and beech woods.

Names of recorded vascular plants follow Mirek *et al*. (2002). The considered taxa encompassed the protected species listed by the Ministry of Environmental Protection (Regulation… 2004), as well as species found on 'red lists' for Poland (Jasiewicz 1981; Zarzycki & Szeląg 1992; Kaźmierczakowa & Zarzycki 2001) and its northwestern regions: Pomerania (Żukowski & Jackowiak 1995), Wielkopolska (Żukowski & Jackowiak 1995), Gdańsk Pomerania (Markowski & Buliński 2004); as well as a list of threatened plant species of mires (Jasnowska & Jasnowski 1977). Also the vascular plant species from the elementary and local CORINE lists, as well as the species encompassed by the Bern Convention and Habitats Directive were acknowledged.

3. Results

3.1. Characteristics of habitats in the studied spring complexes

Typical spring complexes encompass the sites of underground water outflow and the watercourses carrying the water away from the springs, as well as the accumulated humus-rich hummocks and drying deposits of spring sediments. In many places, underground water flows out within spring niches, which formed due to the erosion of steep slopes surrounding them. Quite often – in springs and in eroded spring mires – deposits of spring travertines (limy precipitates from springs) are exposed.

The spring plant cover consists primarily of moss phytocoenoses from the class *Montio-Cardaminetea*, as well as independent bryophyte communities that develop on the hard bottom of the springs. Humus-rich hummocks are often overgrown by *Cardamineto-Chrysosplenietum alternifolii*. *Glycerietum nemoralis-plicatae* and *Cardamino-Beruletum erecti* phytocoenoses from the class *Phragmitetea* can be found along the streams carrying water away from springs.

Alnus glutinosa woods are located in the area of springs and percolating mires. They grow primarily on the peaty substrate at waterlogged sites. In places where underground water supply is plentiful, the development of *Cardamino-Alnetum glutinosae* with the constant participation of *Cardamine amara* and spring mosses belonging to the class *Alnetea glutinosae* can be observed. In areas of somewhat lower moisture, alder-ash woods thrive (*Fraxino-Alnetum cardaminetosum* from the class *Querco-Fagetea*).

Originally, mesotrophic rich fens took up significant areas in the valleys of Pomeranian rivers. Presently, as a result of prolonged changes in hydrological conditions, these mires cover only small areas. They are usually components of extensive peatlands, which vary

Table 1. The occurrence of protected, rare and threatened species in spring complexes in the central part of Polish Pomerania

Species	Habitat types								Polish national and regional «red lists»										
	Number of sites	Springs and their outflows	Rush and sedge communities	Mesotrophic rich fens	Meadows and tall forb communities	Alder woods	Alder-ash wood	Oak-hornbeam and beech woods	Protection in Poland	Kaźmierczakowa and Zarzycki (eds.) 2001	Zarzycki and Szeląg 1992	Żukowski and Jackowiak 1995 (Pomerania)	Żukowski and Jackowiak 1995 (Wielkopolska)	Markowski and Buliński 2004	Jasnowska and Jasnowski 1977	Jasiewicz 1981	CORINE List	Bern Convention	Habitats Directive
Achillea ptarmica	16				x										R				
Actaea spicata	9							x				V	V	LC					
Asarum europaeum	1						x		!			V		NT					
Betonica officinalis	4				x							V	V						
Blechnum spicant	2							x	!!			E	E	VU		RL			
Calamagrostis stricta	7		x	x									V		R				
Campanula latifolia	3					x			!!		R	V	E	NT					
Cardamine flexuosa	2							x				V	I	NT					
Cardamine impatiens	2						x				R	R	DD						
Carex cespitosa	23		x	x	x	x	x							NT	R				
Carex diandra	9			x								V	V	NT	R				
Carex dioica	3			x								E	E	VU	R				
Carex disticha	2				x							V	V	NT					
Carex flava	4			x	x										R				
Carex lepidocarpa	4			x								V	V	LC	R				
Carex limosa	5			x					!!	LR	V	V	E	NT	R				
Carex pulicaris	2			x					!!	VU	V	E	Ex	EN	V	R			
Centaurium erythraea	5				x				!!										
Cephalanthera rubra	1							x	!!	EN	E	E	E	EN					
Chrysosplenium oppositifolium	1	x									R	E	E		V				
Circaea intermedia	7						x					K	K	DD					
Cladium mariscus	1		x						!!			R	R	NT	R				
Convallaria majalis	16							x	!										
Corydalis cava	1							x						NT					
Corydalis intermedia	7							x				R	R			RL			
Corydalis pumila	1							x	!!	VU	R	R	R			R			
Cypripedium calceolus	1						x		!!	VU	V	E	E	EN		V	x	x	x
Cystopteris fragilis	3							x						LC		RL			
Dactylorhiza fuchsii	13			x	x	x			!!		V			VU					
Dactylorhiza incarnata	3			x	x				!!				V	VU	R				
Dactylorhiza maculata	12			x	x				!!		V	V	V	VU					
Dactylorhiza majalis	26			x	x				!!				V	NT	R				
Daphne mezereum	6						x	x	!!			R	R	LC					
Dentaria bulbifera	2							x				V	V						
Dianthus superbus	1		x		x				!!		V	E	V	EN	R	V			
Digitalis grandiflora	2				x				!!					NT					
* *Digitalis purpurea*	3							x	!!										
Drosera intermedia	1			x					!!		V	V	V	VU		R			
Drosera rotundifolia	4			x					!!		R	I	V						
Dryopteris cristata	7			x							V	V	E	NT	R	V			
Eleocharis quinqueflora	3			x								V	V	VU	R				
Epipactis helleborine	9						x	x	!!										
Epipactis palustris	12			x	x				!!		V	V	V	VU					
Equisetum telmateia	3		x			x			!!			R	R	NT	V				
Eriophorum latifolium	5			x								V	V	EN	R				
Euphrasia rostkoviana	4				x									VU					
Festuca altissima	21							x					E						

Frangula alnus	28						x		!										
Gagea spathacea	6							x			V	V	E	NT		R			
* *Galanthus nivalis*	2						x		!!			I	I	DD					x
Galium odoratum	23							x	!										
Glyceria declinata	2	x	x			x						I	I	DD		R			
Glyceria nemoralis	25	x	x			x						R	V	NT	V	RL			
Hammarbya paludosa	1			x					!!	EN	V	E	E	EN		R	x		
Hedera helix	17							x	!										
Hepatica nobilis	17							x	!!										
Huperzia selago	2							x				V	E	NT		RL			
Hydrocotyle vulgaris	27			x											R				
Juncus acutiflorus	1			x							R	V	V	DD	R				
Juncus alpinus-articulatus	5			x								V	V	VU	R				
Juncus subnodulosus	4			x	x						V	V	V	VU	R	R			
Lathyrus niger	1							x											
Lathyrus palustris	1				x						V	V	V	VU	R				
* *Leucojum vernum*	2						x		!!		V		I						
Listera ovata	15				x		x	x	!!				V						
Lonicera periclymenum	3						x		!!				V	VU					
Lysimachia thyrsiflora	6			x											R				
* *Matteuccia struthiopteris*	1						x		!!			V	E	NT		R			
Menyanthes trifoliata	22			x	x				!										
* *Mimulus guttatus*	5	x												NT					
Nasturtium officinalis	3	x	x			x			!!			V	V						
Neottia nidus-avis	2							x	!!			V	E	NT					
Ophioglossum vulgatum	2				x				!!			V	V	VU					
Parnassia palustris	8			x	x										R				
Pedicularis palustris	3			x					!!			V	V	VU	R				
Phegopteris connectilis	1							x					R						
Platanthera bifolia	14				x		x		!!			V	V	VU					
Platanthera chlorantha	4				x		x		!!			E	E	EN					
Poa remota	6	x				x	x					V	E	VU	R				
Polemonium caeruleum	3		x		x				!!	VU		V		VU	V	RL			
Polygonatum verticillatum	2							x				V	E	VU		RL			
Polypodium vulgare	20							x	!!										
Rhynchospora alba	3			x								V	E	NT	R				
Ribes nigrum	26					x	x		!										
Rumex aquaticus	2		x									V	E	NT					
Rumex sanguineus	18					x	x					V	V	NT					
Sanguisorba officinalis	6				x									VU					
Saxifraga hirculus	1			x					!!	EN	E	E	Ex	CR	E	V			x
Selinum carvifolia	17				x									NT					
Stellaria uliginosa	34	x				x	x					V	V		R				
Trollius europaeus	12				x				!!			V	V	VU					
Utricularia intermedia	1			x					!!			V	E	VU	V				
Utricularia minor	3			x					!!			V	V	NT	R				
Utricularia vulgaris	5			x										NT					
Valeriana dioica	25			x	x								V						
Valeriana sambucifolia	7					x							I						
Veronica longifolia	9				x									VU					
Veronica montana	3	x										V	V	NT					
Viburnum opulus	23						x		!										
Vicia sylvatica	6							x				R	R						
Viola mirabilis	2							x				R	R	NT					
Total		8	10	33	28	12	18	28	49	8	21	63	70	67	34	19	2	1	3

Abbreviations: Ex – extinct and probably extinct species; E – endangered species; V – vulnerable species; R – rare and potentially endangered species; I – species of indeterminate category; K – species whose status has been insufficiently researched; RL – regionally or locally rare species; CR – critically endangered species; EN – endangered species; VU – vulnerable species; LR – species of lower risk; NT – nearly threatened species; LC – species of least concern; DD – deficient data on population size; * – anthropophytes naturalized in spring complexes; !! – strict protection; ! – partial protection

in hydrological and trophic conditions, and consequently also in vegetation, representing the alliances *Caricion davallianae*, *Caricion nigrae* and *Caricion lasiocarpae*.

Agriculturally utilized soligenous mires (spring and percolating mires) are dominated by various rush and sedge communities of the class *Phragmitetea*, as well as meadows and tall forb communities of the class *Molinio-Arrhenatheretea*. These were outlined in the works by Osadowski & Wołejko (1997) and Osadowski (2000). The group of communities typical of spring

complexes includes also: *Caricetum paniculatae, Caricetum acutiformis, Caricetum caespitosae, Equisetetum palustris, Crepido-Juncetum subnodulosi* and *Polygono bistortae-Trollietum europaei*.

Beech woods and oak-hornbeam woods are closely connected with spring complexes. They thrive on the mineral soils in the spatial complex of spring niches and hanging spring mires, as well as on the slopes of ravines and gullies from which underground waters flow out. The majority of communities in spring complexes are the typical sub-Atlantic oak-hornbeam wood communities *Stellario-Carpinetum,* as well as acidic beech woods *Luzulo pilosae-Fagetum*, and fertile beech woods *Galio odorati-Fagetum* of the class *Querco-Fagetea*. The floristically rich oak-hornbeam and beech wood communities can be found on moist soils that abound in nutrients, often with calcium deposits originating from spring minerals. From the point of view of phytosociological classification, they include communities that are rare in Pomerania: spring beech woods *Fagus sylvatica-Mercurialis perennis* and orchid beech woods *Fagus sylvatica-Cypripedium calceolus* on travertines (previously known as *Mercurialis-Fagetum* and *Carici-Fagetum*).

3.2. Characteristics of the threatened and protected flora of spring complexes

During the study of spring complexes, the existence of 101 threatened, protected, and rare species was noted. The number of species of this group found on specific site types ranged from 8 to 33, as 8 species were recorded in springs, 10 in rush and sedge communities, 33 in soligenous and intermediate mires, 28 in meadows and tall forb communities, 12 in alder woods, 18 in alder-ash woods, and 28 in beech woods and oak-hornbeam woods (listed alphabetically in Table 1).

Eight species of protected and threatened plants were observed in springs, including: *Glyceria nemoralis, G. declinata, Nasturtium officinalis, Poa remota, Stellaria uliginosa* and *Veronica montana*. The first 3 of the aforementioned species occur also in rush and sedge communities of the class *Phragmitetea*. During field research, the existence of the well-known locality of *Chrysosplenium oppositifolium* was confirmed in a tributary of the river Parsęta. An interesting anthropophyte, *Mimulus guttatus*, was also naturalized in spring communities; its numerous populations were found at the sources of the rivers Grabowa, Wieprza and Słupia.

In sedge and rush communities, 10 protected and threatened species were noted, including: *Calamagrostis stricta*, *Cladium mariscus*, *Carex caespitosa, Equisetum telmateia* and *Rumex aquaticus*. Also *Glyceria nemoralis* is often found growing at spring outflows, while *G. declinata* and *Nasturtium officinalis* are found significantly less often. In sedge communities, on the hummocks of spring mires that were utilized in the past, rare meadow species were recorded: *Dianthus superbus* and *Polemonium caeruleum*.

The largest number of protected and threatened species was discovered in the plant communities of mesotrophic rich fens and intermediate mires. Here, a total of 33 species were found. In soligenous mires, with a steady supply of alkaline or slightly acidic underground water, the presence of *Carex diandra, C. dioica, C. lepidocarpa, C. pulicaris, C. flava, Eleocharis quinqueflora, Eriophorum latifolium, Juncus subnodulosus, J. alpinus-articulatus, Parnassia palustris, Pedicularis palustris, Saxifraga hirculus, Utricularia intermedia, U. minor* and *U. vulgaris* was observed. In intermediate mires, where underground water supply was not as bountiful, so that acidic rainwater dominated, an array of threatened species characteristic of acidic peat bogs was found. These included *Carex limosa, Drosera intermedia, D. rotundifolia, Dryopteris cristata, Hydrocotyle vulgaris, Juncus acutiflorus, Menyanthes trifoliata, Lysimachia thyrsiflora, Rhynchospora alba* and *Valeriana dioica*. In the mires, special attention was paid to orchids, particularly the numerous populations of *Dactylorhiza fuchsii, D. incarnata, D. maculata, D. majalis, Epipactis palustris* and *Hammarbya paludosa*.

Meadows and tall forb communities fed by underground waters often abound in protected and threatened species. Collectively, 28 species were found in those habitats. A significant portion of those species (specifically 11) are common to the rich communities of the class *Scheuchzerio-Caricetea nigrae*; this can be explained by a transformation of rich fens into hay meadows in the past. *Achillea ptarmica, Betonica officinalis, Carex disticha, Centaurium erythraea, Digitalis grandiflora, Euphrasia rostkoviana, Lathyrus palustris, Ophioglossum vulgatum, Sanguisorba officinalis, Selinum carvifolia, Trollius europaeus* and *Veronica longifolia* were found exclusively in those areas. Of special interest is the occurrence of large populations of *Trollius europaeus* and *Juncus subnodulosus,* as well as countless species of orchids, within the spring complexes utilized by people.

Wooded habitats within spring complexes are also rich in protected and threatened species. Specifically, a total of 51 taxa of this group were found there, 12 of which occurred in alder woods, 18 in alder-ash woods, and 28 in beech and oak-hornbeam woods.

The majority of rare and threatened species found within alder woods are typical for spring communities of the class *Montio-Cardaminetea*, as well as for rush communities of *Sparganio-Glycerion fluitantis*. Only in the springs in alder woods was the existence of *Campanula latifolia, Equisetum telmateia* and *Valeriana sambucifolia* noted.

Asarum europaeum, Circaea intermedia, Frangula alnus, Lonicera periclymenum and *Viburnum opulus*, as well as species of anthropogenic origin representing the remnants of human settlements (*Galanthus nivalis, Leucojum vernum* and *Matteucia struthiopteris)* were found exclusively in alder-ash woods. An interesting phenomenon was the presence of *Cypripedium calceolus* in the forests that grow on the shallow chalk deposits of Lake Kwiecko, exposed due to human influence on its hydrologic conditions.

The greatest participation of threatened species was noted in oak-hornbeam and beech woods. Only here the presence of *Blechnum spicant, Convallaria majalis, Corydalis cava, C. intermedia, C. pumila, Cystopteris fragilis, Festuca altissima, Galium odoratum, Hedera helix, Hepatica nobilis, Huperzia selago, Phegopteris connectilis, Polypodium vulgare, Vicia sylvatica* and the anthropogenic *Digitalis purpurea* was confirmed. In more nutrient-rich soils, often abounding in calcium originating from the spring travertines, the occurrence of *Actaea spicata, Cardamine flexuosa, Cardamine impatiens, Daphne mezereum, Dentaria bulbifera, Gagea spathacea, Lathyrus niger, Polygonatum verticillatum* and *Viola mirabilis* was noticed. In spring beech woods, some woodland orchids were found: *Cephalanthera rubra, Epipactis helleborine, Listera ovata* and *Neottia nidus-avis*. Römer (1912) documented the presence of *Cypripedium calceolus* in beech woods in the Radew valley.

4. Conclusions

In the 46 spring complexes in the central part of Polish Pomerania, a total of 101 protected, threatened, and rare species belonging to Poland's 'red lists' were discovered. Excluding the species found in habitats adjacent to spring ecosystems (oak-hornbeam and beech woods), 75 species are directly connected with underground water outflow. The largest number of species of this group (33 species) was found in soligenous and intermediate mires.

The floristic value of the studied spring ecosystems is enhanced by the presence of 49 protected species, 41 of which are strictly and 8 are partly protected. Endangered and vulnerable species deserve special care and attention; these account for a total of 65 species. Moreover, 3 species – *Cypripedium calceolus, Hammarbya paludosa* and *Saxifraga hirculus* – are protected on a larger, European scale.

It must be noted that the floristic data gathered during this study are not meant to exhaust the knowledge of the presence of valuable plant species in spring complexes, but rather they serve as a supplement to the earlier knowledge of the existence of interesting plants within spring complexes of the central part of Polish Pomerania.

On the basis of the results of this study, as well as of other reports on Pomeranian springs, it can be concluded that spring complexes are home to some of the richest populations of protected and threatened species, and at the same time, are the most endangered wetland ecosystems in Poland. Their role has previously been determined as one that is particularly important for nature preservation (for example, in the formation of the European ecological network Natura 2000). However, the effectiveness of their protection is still insufficient. This is linked to the inadequate knowledge of their ecology. The preservation or restoration of the flora of spring complexes requires the recognition of certain ecological circumstances; this involves extending our knowledge of their spatial variation, genesis and history of development, hydrological conditions, mode of land use, as well as the current dynamics of the plant cover.

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