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Revised distribution and phytosociological data of *Orobanche coerulescens* Stephan in Willd. (Orobanchaceae): Poland in relation to Central Europe

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Abstract: *Orobanche coerulescens* has a Eurasian distribution. The species is classified as extinct at most of its localities at the western limit of its range. Its populations are very scarce and critically endangered in Central Europe. This work presents the current distribution of *O. coerulescens* in Poland, based on a critical revision of herbarium and literature data as well as results of original field research, and reviews its distribution in Central Europe (partly in Eastern Europe). Habitats, plant communities, and migration routes of *O. coerulescens* in Central Europe are discussed. The species was initially known in Poland from now historical localities in Pomerania and the valley of the lower Vistula. In 2000-2011 it was recorded at 9 localities in Podlasie, the Małopolska Upland (Wyżyna Małopolska), and the Łódź Hills (Wzniesienia Łódzkie). Its abundance at the localities ranged from a few to over 1000 shoots. These are the largest populations of *O. coerulescens* at its western and north-western range limits.

Key words: *Orobanche coerulescens*, distribution, habitat, plant communities, migration routes, Poland, Central Europe

1. Introduction

Orobanche coerulescens Stephan in Willd. (Orobanchaceae) has a Eurasian distribution. Its range extends from the Far East, Sakhalin, Korea, Japan, Taiwan, China, Nepal, Mongolia, and the Caucasus all the way to Latvia, Ukraine, and Romania. It is very rare in Central Europe, where it has been reported from Hungary, Slovakia, the Czech Republic, Lower Austria, Germany, and Poland. It is a typical steppe plant, probably a relict of post-glacial wormwood *Artemisia*-steppes in the western part of its range. The species is currently recognized as extinct at the majority of its localities at the western limit of its distribution, and its populations are very scarce in Central Europe (Figs. 1-2). It parasitizes *Artemisia campestris* (Kreutz 1995; Zázvorka 2000; Piwowarczyk & Przemyski 2009; Pusch & Günther 2009).

In Europe, *O. coerulescens* has been recorded mainly in communities of the alliance *Festucion rupicolae* (Soó 1968), order *Festucetalia valesiacae* (Oberdorfer 1990; Rothmaler *et al.* 2002), alliance *Festucion valesiacae* (*Potentillo arenariae-Festucenion pallentis*) (Zázvorka 2000) and the association *Helichryso-Festucetum* of the order *Brometalia erectii* (Hemp 1996). In Europe it grows in dry and semi-dry meadows, steppes, xerothermic grasslands, cultivated fields, and xerothermic shrubs. It colonizes warm alkaline and sandy soils, often rendzinas, on dolomite, chalk, limestone, and basalt bedrocks (Kreutz 1995; Uhlich *et al.* 1995; Hemp 1996; Zázvorka 2000; Piwowarczyk & Przemyski 2009). In Asia it prefers steppes, rocky or grassy slopes, grasslands, cultivated fields, deserts, sandy hillsides, or areas along rivers and near seashores (Zoku 1965; Tolmaczev 1974; Charkevicz 1996; Zhiyun & Tzvelev 1998; Sató 2004). It is reported less frequently from forest glades, forest margins, dry pinewoods, and mixed woods (Malyschev & Peschkova 1979; Krasnoborov 1984; Tzvelev 2006).

The species initially was known in Poland from now historical localities in Pomerania and the valley of the lower Vistula. It has been recently (2001-2011) recorded at 9 localities in Podlasie, the Małopolska Upland (Wyżyna Małopolska), and the Łódź Hills (Wzniesienia

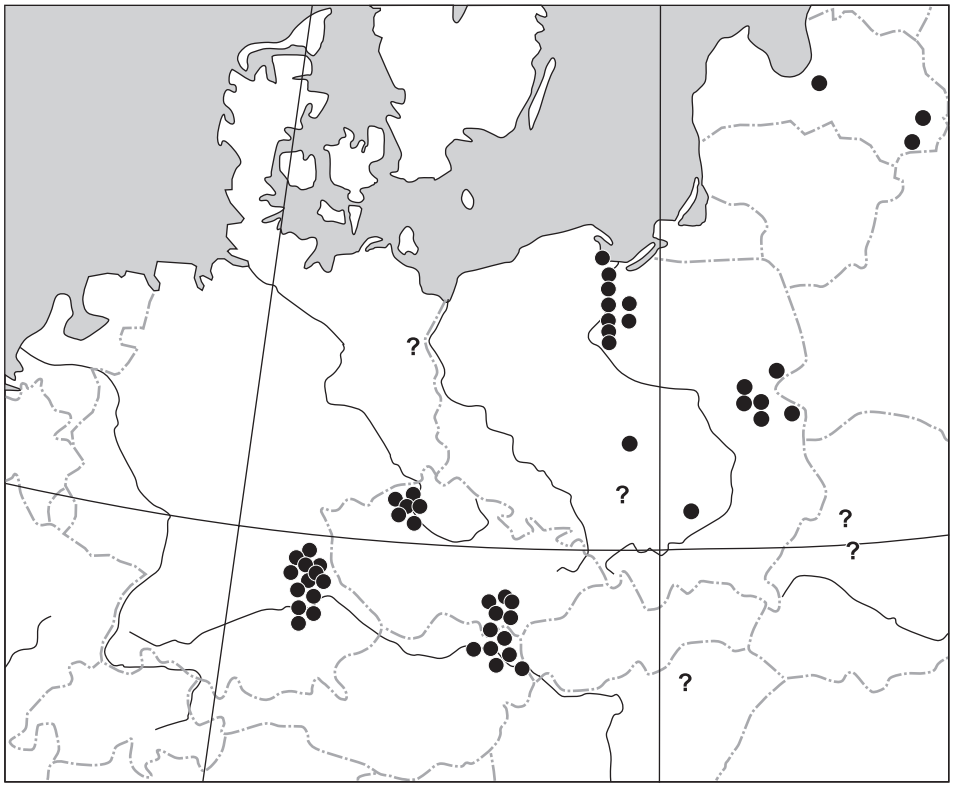

Fig. 1. Distribution of *Orobanche coerulescens* in Central Europe (after Pusch & Günther 2009, modified and supplemented)

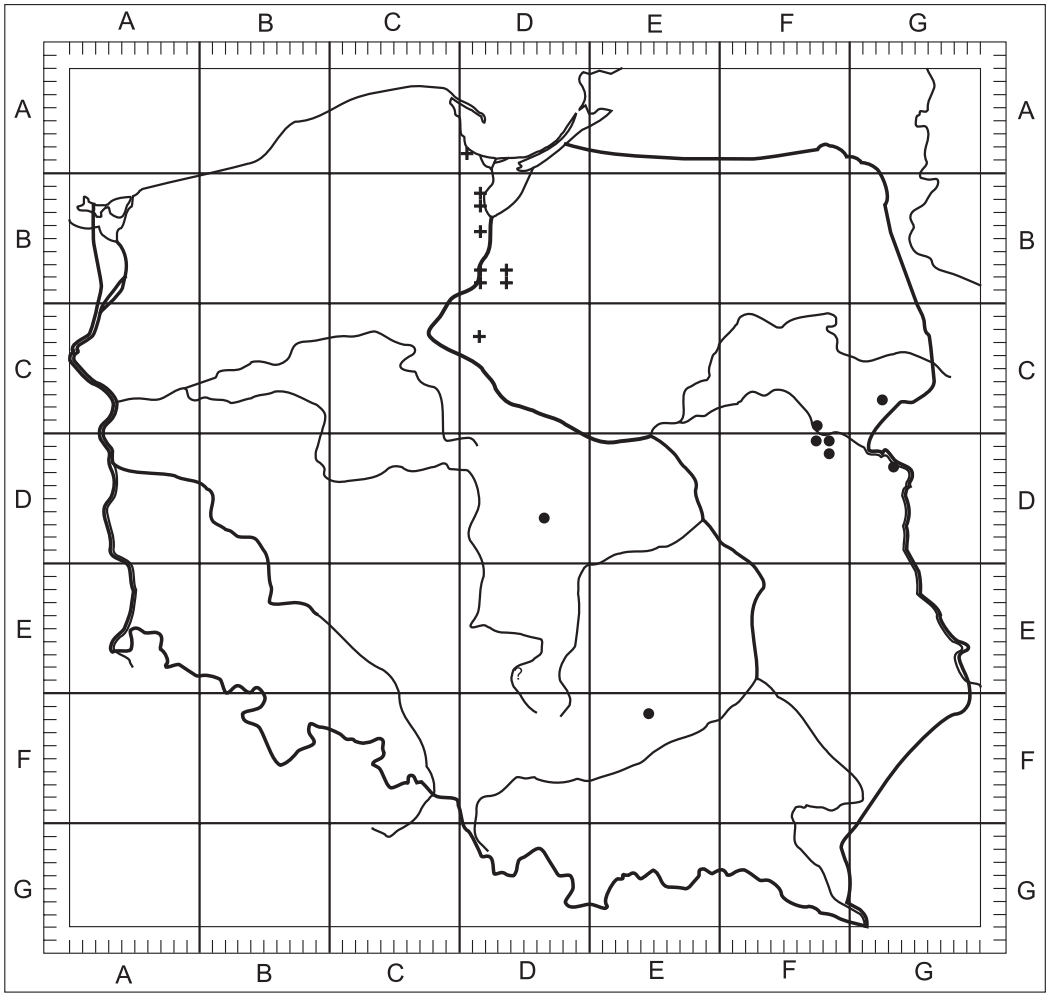

Fig. 2. Distribution of *Orobanche coerulescens* in Poland
Explanations: + – extinct locality, ● – present locality

Łódzkie) (Fig. 2). The abundance of the species at the localities ranges from several to over 1000 shoots.

The aim of this study was to identify the present distribution of *Orobanche coerulescens* in Poland and Central Europe, including some data from Eastern Europe, based on field investigations and verified herbarium and literature data. Preferred habitats, plant communities, threats, and migration routes are also discussed below.

2. Materials and methods

All available herbarium materials of *Orobanche coerulescens* from Poland were revised (KRAM, KTC, OPOL, WA). Herbarium sheets of *O. coerulescens* deposited in herbaria in Slovakia, the Czech Republic, Austria, Germany, Hungary (SLO, PR, PRC, W, GLM-DB, BP) were also examined. Herbarium acronyms are given after Mirek *et al*. (1997) and Holmgren & Holmgren (1998). The nomenclature of vascular plants follows Mirek *et al*. (2002). The nomenclature of syntaxa is based on Matuszkiewicz (2008). The localities are listed in ATPOL cartogram units, 10 km × 10 km (Zając 1978, see also http://www.ib.uj.edu.pl/chronpol/). The units are arranged in alphabetical order. Only localities recorded in my observations and identified or confirmed by me as well as verified herbarium data are listed below. Published data not confirmed by me in the field or undocumented by herbarium material are not reliable, due to frequent determination errors. Localities are described as follows: ATPOL grid unit, geographic location, habitat description, abundance. The following information is also given for most localities: geographic coordinates and elevation (above sea level) (also in Table 1), while for revised exsiccata the collector and collection date, exsiccatum number, and the herbarium acronym. Soil tests were performed at the Regional Chemical-Agricultural Station (Okręgowa Stacja Chemiczno-Rolnicza) in Kielce.

3. Results

In Poland, *Orobanche coerulescens* was known from now historical sites in Pomerania and along the lower Vistula (e.g. Klinsmann 1836; Klinggräff 1854; Bail 1868; Caspary 1871; Abromeit *et al*. 1898). It was classified as probably extinct in Poland until 2001 (Zając & Zając 2001; Zarzycki & Szeląg 2006). *O. coerulescens* was recorded again around 2000 in Podlasie near Bohukały village (Ciosek 2002) and next in Mogielnica, Wasilew Szlachecki, Korczew, Niemojki (Kalinowski 2012), Dobrowoda (R. Piwowarczyk, unpubl. data, 2010) and Tokary (J. & P. Marciniuk, unpubl. data, 2011); in the Nida Basin (Niecka Nidziańska) between Pińczów and Pasturka (Piwowarczyk & Przemyski 2009); and in the Łódź Hills near Smolice (M. Walak, unpubl. data, 2007-2011; R. Piwowarczyk, unpubl. data, 2010) (Fig. 2).

The species was also reported by Mądalski (1967) from Krzyżowa Góra near Olsztyn (DE84). That report cannot be verified as the herbarium material is missing. It was not confirmed during field investigations between 2007 and 2010 (R. Piwowarczyk 2007-2009, unpubl.; Ł. Krajewski unpubl., 2010). The herbarium material found in herbarium OPOL (P/3453, Głuchołazy, leg. Dziatzko 01.07.1901) was verified but it does not correspond to *O. coerulescens*. The species has also been reported from the Lublin region (Fijałkowski 1994) but the location is not specified and the report cannot be verified, as no specimen is available. The list of localities are listed in Appendix.

3.1. Habitat and preferred plant communities in Poland

Orobanche coerulescens occurs in NE Poland (Podlasie) in communities of sandy (psammophilous) grasslands belonging to the alliance *Koelerion glaucae* (class *Koelerio glaucae-Corynephoretea canescentis*). The communities are similar to the *Sileno otitis-Festucetum*, with dominant subcontinental species that also occur in the alliance *Koelerion glaucae* (Table 1). Locally characteristic species include *Silene otites, Dianthus carthusianorum, Centaurea stoebe, Phleum phleoides, Medicago minima*, and *Poa compressa* (Głowacki 1988; Marciniuk 2009). The *Sileno otitis-Festucetum* occurs on permeable sandy or sandy-gravel soils. It occupies secondary habitats, e.g. sand and gravel pits, railway escarpments, wastelands between xerothermic grasslands. The alliance has an intermediate position between typically xerophilous steppe grasslands and sandy grasslands and its delimitation in the system of plant communities is not clear. It has been placed in the classes *Festuco-Brometea* or *Koelerio glaucae-Corynephoretea canescentis*. The alliance is represented in Dobrowoda in Podlasie (Table 1, rel. 1-8) and less evidently in the Nida Basin (Table 1, rel. 9).

A mosaic of the association *Sileno otitis-Festucetum* and the similar *Koelerio-Astragaletum arenarii* is recorded in Dobrowoda. The *Koelerio-Astragaletum arenarii* has been described recently. It covers soils at the initial stage of development, formed on loose or weakly loamy sands, with a constant and quite high contribution of *Astragalus arenarius* (Głowacki 1988). *A. arenarius* is abundant, forming up to ca. 25% of the cover (Table 1). A high cover of the moss layer is recorded, especially by *Racomitrium canescens*, which occupies 60-75% of the area on average (Table 1). Pine from nearby pinewoods intensively self-sows in sandy grasslands. The association occupies acidic or weakly acidic soils according to Głowacki (1988) but soil pH is alkaline in the study area, about 8.0 on average. The

Table 1. Plant communities with *Orobanche coerulescens* (* relevé 1 after Ciosek 2002)

Number of relevé	1	2	3	4	5	6	7	8
Location	Bohukały*	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda
Date	27.06.2001	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010
Area of relevé (m²)	25	25	25	25	25	25	25	25
Exposure	-	SE	SE	SW	SE	SE	SE	SE
Inclination [°]	-	15	10	10	5	5	5	5
Latitude [N]	-	52°33'51"	52°33'51,8"	52°33'51"	52°33'51,7"	52°33'53,5"	52°33'54,1"	52°33'50"
Longitude [E]	-	23°23'22,7"	23°23'28,9"	23°23'32,9"	23°23'34,7"	23°23'36,9"	23°23'39,1"	23°23'26,4"
Altitude (m)	-	170	169	175	175	184	188	183
Density of tree layer A (%)	-	-	-	20	-	-	-	-
Density of shrub layer B (%)	-	10	15	25	10	20	10	25
Density of herb layer C (%)	80	30	60	70	50	75	70	85
Density of moss layer D (%)	40	75	50	30	60	30	15	5
Number of species	40	42	41	41	29	36	35	33
Orobanche coerulescens	+	+	+	+	**1**	+	+	+
Trees and shrubs								
Pinus sylvestris B	.	+	1	2	+	1	+	2
Pinus sylvestris C	.	.	+	.	.	+	.	.
Pyrus communis C	.	+	+	.	.	.	.	.
Ch., D. Ass. *Sileno otitis-Festucetum*								
Poa compressa	.	1	+	+	+	3	+	.
Silene otites	2	2	2	3	2	2	3	+
Centaurea stoebe	1	+	+	+	+	+	+	.
Dianthus carthusianorum	2	.	.	.	.	.	.	+
Phleum phleoides	+	.	.	.	.	.	.	.
Ch. All. *Koelerion glaucae*								
Astragalus arenarius	.	2	1	+	+	+	.	+
Androsace septentrionalis	.	+	+	+	.	+	1	.
Chondrilla juncea	.	1	+	+	+	.	+	.
Plantago arenaria	.	.	.	.	.	.	.	.
Ch. Cl. *Koelerio glaucae-Corynephoretea canescentis*								
Artemisia campestris	1	2	3	3	2	2	2	3
Trifolium arvense	+	1	+	+	+	+	1	+
Sedum acre	.	1	2	2	2	2	+	.
Helichrysum arenarium	1	+	1	+	1	+	+	+
Racomitrium canescens D	1	5	4	3	4	3	1	+
Corynephorus canescens	.	1	+	+	2	+	2	.
Brachythecium albicans D	.	.	.	.	+	+	.	.
Syntrichia ruralis D	.	+	.	+	.	.	.	.
Thymus serpyllum	.	1	.	+	+	+	+	.
Ceratodon purpureus D	2	.	.	.	.	.	.	.
Potentilla argentea	.	.	+	+	.	2	.	+
Jasione montana	.	.	+	.	.	+	1	.
Rumex acetosella	.	.	.	.	.	+	.	.
Ch. O., Cl. *Festucetalia valesiacae, Festuco-Brometea*								
Anthemis tinctoria	.	+	1	1	+	+	+	+
Acinos arvensis	.	+	+	+	.	+	.	+
Potentilla arenaria	.	.	.	.	.	.	.	.
Centaurea scabiosa	.	.	.	.	.	.	.	.
Scabiosa ochroleuca	.	+	.	+	+	.	.	.
Ch. O., Cl. *Arrhenatheretalia, Molinio-Arrhenatheretea*								
Festuca rubra	+	+	1	2	1	+	+	2
Achillea millefolium s. l.	1	.	+	.	.	.	.	+
Daucus carota	.	+	+	.	+	+	+	.
Dactylis glomerata	.	.	.	.	.	.	1	.
Trifolium repens	.	.	.	+	.	+	+	+
Galium mollugo	.	.	.	.	.	+	+	+
Plantago lanceolata	+	.	.	+	.	.	.	.
Trifolium pratense	r	.	.	.	.	+	.	.
Rumex acetosa	.	.	.	.	.	.	+	.
Carex hirta	.	+	1	.	.	+	.	.
Tragopogon pratensis	.	.	+	.	.	.	+	+
Bromus hordeaceus	1	.	.	.	.	.	.	+
Anthyllis vulneraria	.	.	.	+	+	.	.	.
Ch. D. Ass. *Echio-Melilotetum*								
Echium vulgare	.	1	+	+	+	+	1	+
Oenothera biennis cfr.	.	3	2	1	3	2	2	+
Hypericum perforatum	+	+	.	+	.	+	.	+
Melilotus officinalis	.	+	+	+	+	+	.	3
Melilotus albus	.	.	.	.	.	.	.	.
Medicago sativa	.	.	.	.	.	.	.	.
Ch. O., Cl. *Onopordetalia, Artemisietea vulgaris*								
Artemisia vulgaris	+	.	.	.	.	.	.	.
Solidago serotina	.	.	.	+	.	.	.	.
Tanacaetum vulgare	.	.	.	.	.	.	.	.
Artemisia absinthium	.	.	.	.	.	.	.	.

9	10	11	12	13	
Pasturka	Smolice	Smolice	Smolice	Smolice	
28.09.2010	10.09.2010	10.09.2010	10.09.2010	10.09.2010	
25	25	30	25	25	C
S	SSW	S	S	S	o
5	10	30	5	5	n
50°30’36”	51°53’57,3”	51°53’54,6”	51°53’54”	51°53’54,6”	s
20°33’39”	19°34’59,6”	19°34’48,7”	19°34’45,9”	19°34’46,6”	t
227	160	158	161	155	a
-	-	-	-	-	n
-	-	-	10	15	c
85	60	75	90	75	y
15	70	15	30	20	
48	33	24	31	34	
+	+	+	+	+	V
.	.	.	.	.	III
.	.	.	.	.	I
.	.	.	.	.	I
+	3	2	3	3	V
2	.	.	.	.	IV
+	.	.	.	+	IV
+	.	.	.	.	II
4	.	.	.	.	I
.	.	.	.	.	III
+	.	.	.	.	III
.	.	.	.	.	II
+	.	+	.	.	I
4	3	4	4	4	V
3	+	1	1	2	V
2	+	1	.	.	IV
.	.	+	.	.	IV
.	.	.	.	.	IV
.	.	.	.	.	III
1	4	+	2	1	III
+	1	1	+	.	III
.	.	.	.	.	II
+	+	+	.	+	II
					II
.	.	.	.	.	II
.	.	.	.	+	I
.	.	.	.	.	III
.	.	+	.	.	III
.	+	+	1	+	II
+	+	+	+	.	II
.	.	.	.	.	II
1	3	2	2	2	V
+	1	+	2	1	IV
+	+	.	.	.	III
1	1	.	2	1	II
.	.	.	.	.	II
+	.	.	.	.	II
.	+	.	+	+	II
.	+	.	+	.	II
.	.	.	+	+	II
.	.	.	.	.	II
.	.	.	.	.	II
.	.	.	.	.	I
.	.	.	.	.	I
+	+	+	+	.	V
.	+	2	1	1	V
.	+	.	.	+	III
.	.	.	.	.	III
.	+	.	+	+	II
+	.	.	.	+	I
1	.	+	.	+	II
.	1	.	.	+	II
.	+	.	1	1	II
.	+	.	+	+	II

humus horizon is poorly developed (Table 2). Very well smoothed quartz (water environment during transport) dominates in the samples. Feldspar chips as well as pieces of granite, gneiss, and sandstone are also recorded. The soil is post-glacial. This association is recorded mainly in an old sand pit in Dobrowoda. Broomrapes are also found in adjacent communities formed on a railway escarpment. The escarpment and the space between tracks are also occupied by *O. coerulescens*. These are interesting and still poorly recognized communities with the continental species *Gypsophila paniculata* (Głowacki 1988; Table 1) and less developed associations of the suballiance *Dauco-Melilotenion* (order *Onopordetalia acanthii*, class *Artemisietea vulgaris*), e.g. *Echio-Melilotetum*. *O. coerulescens* is scattered at the site in Dobrowoda and colonizes an area of ca. 0.1 hectare.

O. coerulescens occupies similar habitats at the other localities in Podlasie: poor sandy grasslands, often ruderalized, or near arable fields (Tokary). It also colonizes gravel pits (Korczew) or areas near railway lines (Niemojki) (Kalinowski 2012; Marciniuk & Marciniuk msc. 2011).

The species occurs in a wasteland on the margin of a sandy grassland and of an arable field near Pińczów in the Nida Basin in the Małopolska Upland (Piwowarczyk & Przemyski 2009). It grows in a community resembling the association *Sileno otitis-Festucetum* with xerothermic, meadow, ruderal and segetal species also present. The substrate is formed by calcareous sands; soil pH is 7.9 (Tables 1-2).

The locality in Smolice in the Łódź Hills occupies an area of ca. 200 m^2 of sandy slopes or their bases at a former shooting range. *O. coerulescens* grows in ruderalized sandy grasslands. The communities are dominated by species of the class *Koelerio glaucae-Corynephoretea canescentis*, with an admixture of species of the classes *Festuco-Brometea, Molinio-Arrhenatheretea, Artemisietea vulgaris*, and *Stellarietea mediae* (Table 1, rel. 10-13). Soil pH is alkaline and ranges from 7.8 to 8.0 (Table 2). Gravel to silt fractions are recorded in the soil. Its components are: quartz (ca. 70%), weakly smoothed grains, rock fragments: gneiss, sandstones, granites, boulder clay pieces. The soil is composed of post-glacial material.

At its present localities, *O. coerulescens* grows in Poland on calcareous sands in thermophilous grasslands, gravel pits, along railway lines, in a former shooting range, wastelands and arable fields, with a high number of species of the class *Koelerio glaucae-Corynephoretea canescentis*, alliance *Koelerion glaucae*, and order *Festucetalia valesiacae*, and an admixture of meadow (*Arrhenatheretalia*),

Table 1. Cont.

Number of relevé	1	2	3	4	5	6	7	8
Location	Bohukały*	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda	Dobrowoda
Date	27.06.2001	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010	10.06.2010
Area of relevé (m²)	25	25	25	25	25	25	25	25
Exposure	-	SE	SE	SW	SE	SE	SE	SE
Inclination [°]	-	15	10	10	5	5	5	5
Latitude [N]	-	52°33'51"	52°33'51,8"	52°33'51"	52°33'51,7"	52°33'53,5"	52°33'54,1"	52°33'50"
Longitude [E]	-	23°23'22,7"	23°23'28,9"	23°23'32,9"	23°23'34,7"	23°23'36,9"	23°23'39,1"	23°23'26,4"
Altitude (m)	-	170	169	175	175	184	188	183
Density of tree layer A (%)	-	-	-	20	-	-	-	-
Density of shrub layer B (%)	-	10	15	25	10	20	10	25
Density of herb layer C (%)	80	30	60	70	50	75	70	85
Density of moss layer D (%)	40	75	50	30	60	30	15	5
Number of species	40	42	41	41	29	36	35	33
Berteroa incana	.	.	.	.	.	.	.	.
Cichorium intybus	.	.	.	.	.	+	+	.
Melandrium album	.	.	.	.	.	.	.	+
Ch. *Stellarietea mediae*								
Silene vulgaris	.	+	.	.	+	+	.	.
Conyza canadensis	.	.	.	.	.	.	.	.
Vicia villosa	+	.	+	+	.	.	+	+
Vicia hirsuta	.	.	.	.	.	.	.	+
Vicia tetrasperma	.	.	+	.	.	.	.	.
Papaver rhoeas	.	+	.	.	.	.	+	.
Bromus tectorum	.	+	1	.	.	.	.	.
Ch. *Trifolio-Geranietea sanguinei*								
Medicago falcata	.	+	.	+	.	+	.	.
Verbascum lychnitis	1	.	.	.	.	.	.	.
Galium verum	.	.	.	.	.	.	+	+
Coronilla varia	.	.	.	.	.	.	+	+
Clinopodium vulgare	.	+	.	.	.	.	.	.
Ch. *Agropyretea intermedio-repentis*								
Convolvulus arvensis	.	.	+	+	+	.	.	.
Elymus repens	.	.	+	.	.	.	.	.
Equisetum arvense	.	.	.	+	.	.	.	.
Others								
Hieracium pilosella	1	4	1	3	2	4	1	4
Medicago lupulina	+	+	3	1	1	+	3	.
Arenaria serpyllifolia	.	1	+	.	.	.	.	.
Gypsophila paniculata	.	1	+	.	+	+	1	.
Alyssum alyssoides	.	+	+	.	.	.	+	.
Calamagrostis epigejos	.	.	.	+	.	.	.	.
Cerastium arvense	.	.	.	.	.	.	.	.
Eryngium planum	+	.	.	.	.	.	+	+
Cladonia furcata D	1	+	.	.	.	.	.	.
Odontites serotina	.	.	.	.	.	.	.	.
Pimpinella saxifraga	.	.	.	+	.	.	.	+
Barbula unguiculata D	.	.	.	.	.	.	.	.
Bryum caespiticium D	.	+	.	.	.	.	.	.

Sporadic: **Ch., D. Ass. *Sileno otitis-Festucetum*:** *Medicago minima* 9, *Verbascum phoeniceum* 1(1), *Veronica spicata* 9(1); **Ch. Cl. *Koelerio glaucae-Corynephoretea canescentis*:** *Cladina mitis* D 1, *Herniaria glabra* 13, *Polytrichum piliferum* D 1(1), *Trifolium campestre* 1; **Ch. *Festuco-Brometea*:** *Allium oleraceum* 1, *Asparagus officinalis* 9, *Carex praecox* 1(1), *Carlina vulgaris* 1, *Hieracium bauhinii* 1(2); **Ch. *Molinio-Arrhenatheretea*:** *Cnidium dubium* 1(1), *Festuca pratensis* 1(1), *Holcus lanatus* 1(1), *Knautia arvensis* 9, *Leucanthemum vulgare* 1, *Lolium perenne* 9, *Taraxacum officinale* s.l. 13, *Trifolium dubium* 3; **Ch. *Artemisietea vulgaris*:** *Picris hieracioides* 9, *Anchusa officinalis* 3, *Urtica dioica* 3; **Ch. *Stellarietea mediae*:** *Fallopia convolvulus* 9, *Vicia angustifolia* 1(1); **Others:** *Abietinella abietina* D 4, *Agrostis capillaris* 8, *Betula pendula* C 12, *Briza media* 1, *Cetraria aculeata* D 2, *C. islandica* D 2, *Cladonia cornuta* D 9, *C. fimbriata* D 9, *C. glauca* D 9, *C. pyxidata* D 10, *C. symphycarpa* D 12, *Erigeron acris* 1, *Juniperus communis* C 3, *Orobanche arenaria* 9, *Peltigera polydactyla* D 4, *P. rufescens* D 5, *Peucedanum oreoselinum* 1(2), *Pinus sylvestris* A 4(1), *Populus nigra* B 13(1), C13, *P. tremula* A 4(1), *Prunus spinosa* C 9, *Pyrus communis* B 3, *Salix caprea* A 4, B 4, *Sedum maximum* 9, *Senecio jacobaea* 1, *S. vulgaris* 8, *Solanum tuberosum* 8, *Solidago virgaurea* 1(2), *Tussilago farfara* 13

ruderal (*Echio-Melilotetum*, *Onopordetalia*), and segetal (*Stellarietea mediae*) species. It prefers south-facing sites: S, SE and SW (Table 1). Communities occupied by *O. coerulescens* cannot be classified as sandy grassland. They are not sufficiently well-defined, as the system of plant communities is mostly pioneer and mosaic. Similar habitats are occupied by *O. arenaria* at its locality near Pińczów, where it grows together with *O. coerulescens* (Piwowarczyk 2012a; Piwowarczyk & Przemyski 2009, 2010).

3.2. Population size

Local populations in Central Europe are not very large. They usually consist of a few individuals, sporadically up to 20-30 in the Czech Republic and Germany, and their flowering is observed irregularly, often

9	10	11	12	13	
Pasturka	Smolice	Smolice	Smolice	Smolice	
28.09.2010	10.09.2010	10.09.2010	10.09.2010	10.09.2010	
25	25	30	25	25	C
S	SSW	S	S	S	o
5	10	30	5	5	n
50°30'36"	51°53'57,3"	51°53'54,6"	51°53'54"	51°53'54,6"	s
20°33'39"	19°34'59,6"	19°34'48,7"	19°34'45,9"	19°34'46,6"	t
227	160	158	161	155	a
-	-	-	-	-	n
-	-	-	10	15	c
85	60	75	90	75	y
15	70	15	30	20	
48	33	24	31	34	
+	.	.	+	.	I
.	.	.	.	.	I
+	.	.	.	.	I
.	+	+	1	+	III
+	2	1	1	+	II
.	.	.	.	.	II
+	.	.	+	.	II
+	.	.	.	+	II
.	.	.	.	.	I
.	.	.	.	.	I
+	+	.	+	.	III
+	.	.	.	.	I
.	.	.	.	.	I
.	.	.	.	.	I
+	.	.	.	.	I
.	.	.	.	.	II
+	.	.	.	.	I
.	.	.	.	+	I
.	1	2	2	2	V
+	+	.	+	.	IV
+	+	+	.	+	III
.	.	.	.	.	II
.	.	.	.	.	II
.	.	.	+	+	II
.	+	+	.	+	II
.	.	.	.	.	II
.	.	.	.	.	I
.	+	.	+	.	I
.	.	.	.	.	I
.	+	.	+	.	I
.	.	+	.	.	I

at long-term intervals (Hemp 1996; Holub & Zázvorka 1999; Zázvorka 2000).

The number of individuals varies greatly at Polish localities, from several to over a thousand shoots. About 290 shoots were recorded near Pińczów in 2007 (Piwowarczyk & Przemyski 2009) but wastelands and partly the grassland were ploughed the following year, alfalfa was sown and weed-killing agents were used. The population abundance decreased dramatically and only ca. 50 shoots were recorded in 2009 and 40 in 2011 (R. Piwowarczyk, unpubl. data). Nineteen shoots occurred near Bohukały village in Podlasie in 2001 (Ciosek 2002); over 1000 shoots near Dobrowoda in 2010 (R. Piwowarczyk, unpubl. data); 10 in Mogielnica in 2010; 95 in Wasilew Szlachecki in 2010; 3-6 in Korczew in 2005-2010; 72 in Niemojki in 2001 (Kalinowski 2012); over 230 shoots in Tokary in 2011 (J. & P. Marciniuk, unpubl. data). The population in Smolice has been observed since 2007, when it consisted of 7 shoots. Its abundance and the area has increased gradually since 2007, as 13, 20 (M. Walak, unpubl. data) and over 100 shoots (R. Piwowarczyk, M. Walak, unpubl. data) were recorded in 2008-2010, and over 230 shoots in 2011 (M. Walak, unpubl. data). At present the localities in Dobrowoda and Smolice are probably the richest local populations of the species in Central Europe.

3.3. Threats and protection indications

Orobanche coerulescens is strictly protected in Poland. It was considered as probably extinct until 2001 (Zarzycki & Szeląg 2006) and at present it is included in the Red Data Book as a critically endangered (CR) species (Piwowarczyk 2012b). Many of its populations colonize disturbed, temporary habitats. Further survival of *O. coerulescens* localities depends chiefly on extensive farming, which hinders the increase in grassland cover and its overgrowing by trees and shrubs. Intensive farming, and mostly the use of weed-killing agents, are main threats to the locality near Pińczów. Numerous affected individuals of *O. coerulescens* and its host plant were observed in 2008. Ploughing also has an adverse effect at these localities and causes a drastic

Table 2. Soil analysis of selected *Orobanche coerulescens* localities

Sample	pH in H_2O	Salinity (g NaCl/ l of soil)	Humus (%)	Nutrients (mg/l of soil)						Contributions (%) of particle size classes of fine earth fraction (diameter >2 mm)			
				N-NO3	P	K	Mg	Ca	Cl	Sand (2.00-0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)	Fine particles (<0.02 mm)
1	7.9	0.12	1.05	43	97	66	52	1440	<37	98.23	1.77	0.00	0.92
2	7.8	0.12	0.84	45	13	40	88	1880	<37	97.73	2.27	0.00	0.91
3	8.0	0.16	0.61	70	11	43	101	2530	<37	98.94	1.06	0.00	0.39
4	8.0	0.12	0.67	60	13	29	122	2300	<37	98.53	1.47	0.00	0.56
5	7.9	0.14	0.73	63	11	38	102	2580	<37	96.42	3.58	0.00	1.16

Explanations: samples 1 – Pasturka, 2-3 – Smolice, 4-5 – Dobrowoda

drop in the population and habitat abundance. Mechanical factors, i.e. crushing by motor vehicles, site re-opening, and secondary succession, especially by an increased abundance of abandoned sandy grasslands and by abundant pine self-sown seedlings from adjacent pinewoods, pose major threats to the population in the gravel pit in Dobrowoda. Populations near railway lines (Dobrowoda or Niemojki) are threatened by herbicides used to prevent track overgrowing, as herbicide-burnt individuals have been observed in Niemojki (Marciniuk & Marciniuk msc. 2011). Waste materials, rubble, and soil are stored in the former shooting range near Smolice. This leads to habitat changes and causes possible mechanical crushing of plants.

4. Discussion

Orobanche coerulescens is extremely rare at the western limit of its continuous range and is considered as a critically endangered species (Korneck *et al*. 1996; Holub & Zázvorka 1999; Niklfeld & Schratt-Ehrendorfer 1999; Feráková *et al*. 2001; Piwowarczyk 2012b). It is found at only several extant localities in individual countries. The majority of data on its occurrence in Central Europe dates from the 19th and early 20th centuries and is now historical. In the Czech Republic *O. coerulescens* is a rare species, known from 25 localities, mostly historical. Its populations are small, consisting of only 1-5(-30) plants. It occurs in relict rocky and xerothermic grassland, usually on basalts and limestones in the warmest regions, i.e. Northern Bohemia (České středohoří hills) and southern Moravia. *O. coerulescens* does not spread to new localities and the number of its local populations is declining. It has recently been confirmed at only 6 of them: the vicinity of Raná hill near Louny, the vicinity of Litoměřice: Bílinka, Kalvárie hill near Velké Žernoseky, Radobýl hill, in southern Moravia: Újezd u Brna, Špice hill, and Ječmeniště near Dyjákovičky (Holub & Zázvorka 1999; Zázvorka 2000). Recent reports of this species come from Labské středohoři (Hadinec & Lustyk 2009). It is still extant on Raná hill (Zázvorka unpubl. data, 2011). In Slovakia, the only locality was Devínska Kobyla hill near Bratislava; older collections have not been confirmed (Zázvorka 1997, unpubl. data, 2011). In Germany, it currently occurs most probably only in Bavaria (Frankenalb) and the vicinity of Regensburg: Altmühltal. Those German populations usually consist of only 1-5 shoots, infrequently 10-20 (Hemp 1996; Scheurer 2006; Pusch & Günther 2009). It was reported in the 20th century from Brandenburg but most probably erroneously: between Oderberg and Liepe (Pusch 1996). In Hungary it was reported from now historical or erroneously identified localities near Budapest, Dorog, Budaci, Sajólád (Tibor 1992; Virók 2009). These few earlier records are misidentifications or have no available voucher specimens. In the BP collection, there is only one specimen labelled as *O. coerulescens*, from Rakós in Budapest (leg. Borbás V., 03.06.1871, BP, 07791), but it does not correspond to this species (rev. Piwowarczyk R., 2011). The majority of localities reported from Lower Austria have not been confirmed (Pusch & Günther 2009). It has been sporadically reported from Ukraine, from the Roztocze, Kremenets, and Tarnopol regions, forest steppes in Podolia, and steppes (Kotov 1999) but specific information was rarely provided and the localities require verification. In Latvia, it was recorded on a railway line in Riga and later near Ilgas (40-50 individuals were observed in the 20th century). Further localities have been reported from a dry fallow-land in south-eastern most Latvia, e.g. Aglona (www.latvijasdaba.lv). It was recorded in Sikele in 2000 (Evarts-Bunders 2003) and then near Veckaplava in 2008, both in the Daugavas loki park. The species occurs there in wastelands and is threatened by competition with grass and shrubs and by a close proximity of fields (Bara 2010) (Fig. 1). The 9 local populations discovered in Poland considerably enrich the area of its distribution in Central Europe.

Preferred plant communities of this steppe species at its western range limit are infrequently discussed in the literature. Little information is also available from the centre of its range. *Orobanche coerulescens* in Central Europe prefers thermophilous grasslands similar to xerothermic steppe grasslands, with a contribution of distinctly continental or subcontinental species. In the Czech Republic these are communities of the alliances *Festucion valesiacae* and *Alysso-Festucion pallentis*, suballiance *Potentillo arenariae-Festucenion pallentis* (Zázvorka 2000). In Pegnitzalb in Germany, these are mainly patches belonging to the association *Helichryso-Festucetum* (order *Brometalia erecti*) (Hemp 1996). In Poland *O. coerulescens* is mostly recorded in mosaic communities of the alliances *Koelerion glaucae* and *Festucetalia valesiacae*. The altitude range of the species at its extant localities in Poland is between 150 and 230 m. It is up to 450 m on average in Central Europe (Pegnitzalb) (Pusch & Günther 2009) and between 900 and 4000 m in China (Zhiyun & Tzvelev 1998).

Natural and seminatural habitats colonized by *O. coerulescens* have been diminishing, while substitutive or secondary, human-affected habitats are expected to be more frequent. This is largely caused by its range limit in Poland and in Europe, as *O. coerulescens* is a typical component of cold *Artemisia* steppes. It is difficult to determine whether its records can be classified as primary, relict occurrences of the numerous species representing the steppe elements, in Poland, or they result from relatively new migration (Paul 2010). *O. coerulescens* colonizes these newly formed habitats

while more or less naturally expanding its area of distribution. As well as being recorded in natural or seminatural habitats, i.e. thermophilous grasslands, *O. coerulescens* is also observed on semi-ruderal or anthropogenically transformed habitats, such as ecotones of fields and grasslands, wastelands, gravel pits, and along railway lines, e.g. Dobrowoda, Niemojki, Korczew in Poland (Piwowarczyk & Przemyski 2009; Piwowarczyk 2012a,b; Kalinowski 2012; Marciuniuk & Marciniuk msc. 2011) or near Riga in Latvia (www.latvijasdaba.lv) and slopes along railway lines, e.g. Libochovany and Velké Žernoseky (Hadinec & Lustyk 2009). The species has also been reported as an apophyte and a ballast plant in the flora of Gdańsk (Schwarz 1967). Its spread onto such habitats is encouraged by transport routes, e.g. with aggregate from gravel pits, by rail, possibly with ballast material from ships (formerly in Pomerania and the lower Vistula valley) or agriculture. In the Czech Republic, *O. coerulescens* was observed only in natural habitats but it was once found on Kalvárie hill near Velké Žernoseky (N Bohemia) on top of the ruins of a vineyard house but close (no more than 50 meters) to its natural occurrence on the rocks. The second, somewhat subruderal occurrence was recorded in southern Moravia near Ječmeniště on the Austrian border. It grew on terraced slopes in the past, together with *O. arenaria* (Zázvorka, by letter 2011).

It is interesting when *O. coerulescens* appeared in Central Europe. Most probably the steppe species (including host species of the genus *Artemisia*) began to migrate more intensively during the last glaciation, especially towards the end of the last glacial period and in the older post-glacial period. Vast forestless areas made the migration of steppe plants easier, which was also encouraged by the dry and cold continental climate (Pawłowska 1959). The newly discovered localities in Poland, especially in the Łódź Hills and in Podlasie, i.e. in the Podlasie Bug Gap (Podlaski Przełom Bugu) and Drohiczyn Plateau (Wysoczyzna Drohiczyńska), are located on gravel hills and terminal moraines of the maximal range of the Saalian glaciation (=Warthe Stage). Soils are mostly composed of sands and glacial-river loams and till with gravel and boulders, often also in the terminal glacial accumulation zone (Ostrowski 1966; Różycki 1969; Kondracki 2001). *O. coerulescens* is very likely to be a relict of one of a few migration waves dating from the end of the Pleistocene to the beginning of the Holocene, which arrived in Poland via this route. Given the present continuous range of *O. coerulescens*, it is highly probable that the main migration route stretched from the south-east in the Pontic areas and Podolia across the Dniester and along the northern edge of the Carpathian Mts. and from the south from the Pannonian Plain. The migration route of *O. coerulescens* in Poland most probably depended on suitable habitats, i.e. along valleys of large rivers, such as the Bug or Vistula, or along plateau edges.

Habitats occupied by *O. coerulescens* are threatened due to the proximity to farmland and the impact of herbicides. Secondary succession is another important threat. The newly discovered localities of *O. coerulescens* in Poland and the extant localities in Central Europe should be recognized as relict and critically endangered sites where special protection measures must be used. They should be included in an environmental monitoring programme with local active protection. Preferably they should be protected as ecological sites (Polish: *użytki ekologiczne*).

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Appendix. List of localities of *Orobanche coerulescens*

DA: 80 – Westerplatte, now part of Gdańsk, Weiss 1825 (sandy sites on Westerplatte, Weiss reports *O. purpurea* [orig. *O. coerulea*] but his description suggests it could be *O. coerulescens*); Klinsmann 1836 („on Westerplatte in June, it is definitely also the same broomrape that Weiss observed, recognizing it as *O. coerulea*"); Meyer 1834 (Meyer also stresses that the species was often confused with *O. purpurea* and can be present under this name at many other localities); Klinggräff 1854, 1861/1862; Klinsmann 1865 (Klinsmann stresses the negative influence of collectors, leading to the disappearance of species like *O. coerulescens*); Klinggräff 1866a (*O. coerulescens* re-recorded on Westerplatte on 9 July 1865 by Italiener and Retowski); Klinggräff 1866b (Klinggräff stresses that the species is ruthlessly collected „Ausser bei Danzig auf der Westerplatte wo sie jetzt übrigens durch schonungsloses Sammeln selten geworden"); Bail 1868 (species re-recorded); Bail 1880; Abromeit *et al*. 1898 (after Gereke 1821); Beck 1890, 1930; Gdańsk, Vistula valley „Fahrwasser„ (Abromeit *et al*. 1898 after Ross 1872); Herbarium materials: Westerplatte, leg. Klinsmann s.d. (probably in 1836?), GLM-DB (149837); Seite prope Gedanum et communic. ab amico Oenicke 1838, W; Prope Gedanum communic. Krahn 1849, W; Westerplatte, leg. Oenicke s.d., leg. Schumann s.d., W; Westerplatte, leg. H. K. Schmidt s.d., PR; Prope Gedanum, leg. Buek s.d., W; Gedanum, Buek s.d., SLO; Prope Gedanum leg. Beck s.d., W; Westerplatte, leg. H. R. Schmidt, s.d., ex herb. Wallroth, PR; **80 –** Siedlce near Gdańsk (Bail 1870, 1873; Abromeit *et al*. 1898 after Bail; Beck 1930). **DB: 11** – Tczew (Beck 1930); **21** – loamy-sandy slope of Vistula valley between Gorzędziej and Mała Słońca near Tczew (Caspary 1871; Abromeit *et al*. 1898 after Caspary; Preuss 1912); **41** – Gniewskie Młyny (Jakobsmühle) (Bail 1870; Abromeit *et al*. 1898 after Bail; Preuss 1912); on a high, loamy bank of Wierzyca river between Brody and Brodzki Młyn near Gniew (Caspary 1871; Abromeit *et al*. 1898 after Caspary and Scholz); Gniew („Städtischen Anlagen bei Mewe„) (Scholz 1910-11; Beck 1930 after Scholz; Preuss 1912); **71** – Bingsbergen, hill near Zakurzewo (leg. Grütter, 1891, WA 33095; Abromeit *et al*. 1898 after Klinggräff 1874 and Peil 1886; Preuss 1912); **81** – on a slope between citadel and Vistula valley in Grudziądz (Klinggräff 1861/1862, 1866b after Helmrich 1861); sandy slope of Vistula valley, N of citadel in Grudziądz up to Bingsbergen hill (Scholz 1896; Abromeit *et al*. 1898 after Scholz; Preuss 1912); Grudziądz (Beck 1930); **83** – balks near Łasin (Abromeit *et al*. 1898 after Schemmel 1897; Preuss 1912; Beck 1930); **DC: 21** – sandy hill between Gronowo and Judamühle, district of Toruń town (Abromeit *et al*. 1898 after Frölich 1883); **DD: 66** – Smolice near Łódź, a former shooting range SSE of Smolice, ruderalized poor sandy grassland (M. Walak, unpubl. data 2007-2011; leg. R. Piwowarczyk, 10.09.2010, KTC); **EF: 14** – Pasturka near Pińczów (leg. R. Piwowarczyk, 2007, 2009, KTC; Piwowarczyk 2011, 2012; Piwowarczyk & Przemyski 2009, 2010); **FC: 97** – thermophilous grasslands, Mogielnica, Wasilew Szlachecki (Kalinowski 2012); **FD: 07 –** Korczew (Kalinowski 2012); **08 –** Tokary, ruderalized sandy grassland (J. & P. Marciniuk, unpubl. data, 2011); **18** – Niemojki (Kalinowski 2012), **GC: 72** – Dobrowoda near Kleszczele, sandy grasslands in an old gravel pit, also by railway lines (Ł. Dawidowicz unpubl. data, 2010; leg. R. Piwowarczyk, 10.06.2010, KTC); **GD: 23** – Bohukały (Ciosek 2002).

R e m a r k : a specimen in Polish collections documents a locality in the Czech Republic: on a steppe of a basalt mountain (Raná hill) near the village Raná near Louny, Teplice district, leg. J. Mądalski, 03.08.1958 (KRAM, 494734).