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Euphrasia's hide-and-seek: periodicity of occurrence in some high-mountain species of Euphrasia (Orobanchaceae) and its consequences for botanical research on protected areas

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Keywords: Euphrasia, periodicity, protected areas, botanical research

Abstract

The paper presents the results of long-term observations made on selected populations of two high-mountain *Euphrasia* species. The monitoring was conducted during 2002–2016 in ranges of the Polish parts of the Carpathians and Sudetes. Field studies revealed periodical occurrence and disappearance of populations in the localities for one or more seasons, which may be connected with the life cycle of annual plants. The phenomena of *periodicity occurrence* and *seed dormancy* and their consequences are discussed.

Introduction

The genus *Euphrasia* (eyebright) is represented by ca. 350 species worldwide (Fischer 2004). High-mountain eyebright species occur at altitudes up to 4450 m a.s.l. in the Himalayas (Li 1953). In Europe, eyebright species have been found in almost all mountain ranges at altitudes as high as 2700 m a.s.l. (in the Alps) (Yeo 1978). There are 11 species of eyebright in Poland (Posz 2014, 2016), three of which, *E. minima* Jacq., *E. picta* Wimm. and *E. corcontica* (Smejkal) Smejkal et Dvořáková, are high-mountain species. These species are typical for siliceous bedrock. The range of *E. salisburgensis* Funck is also limited to mountain areas, but it prefers calcareous bedrock.

European eyebrights are small, semi-parasitic herbaceous annuals, which range in height from several centimetres to nearly twenty centimetres. The double-lipped, dorsiventral flowers are most often white (though occasionally yellow or blue), with a yellow spot on the lower petal, with individual leaves situated radially around the stem (Figure 1). Eyebrights are therophytes, meaning that their entire life cycle from germination to producing their own seeds takes place within a single growing season. After producing seeds, the plants die off, creating a soil seed bank.

Given the high number of differences found within individual species, the high number of hybrids, and their overlapping ranges, it should be said that *Euphrasia* genus taxa are difficult to identify. The existence of atypical forms, probably as a result of semi-parasitism, creates additional problems. Their morphological traits (number of flowers, branches, height) depend on the presence or absence of host plants (Crosby-Brown 1950; Philipson 1959; Wilkins 1963; Yeo 1961, 1964). Parasitism contributes to significant morphological diversity even within one population.

Field studies over many years revealed the periodical occurrence and disappearance, for one or several seasons, of certain populations in the localities. This phenomenon was called *periodicity* (Posz 2014; Proszkiewicz 2006) and is probably connected with the annual life cycle and seed dormancy in the soil seed bank. The possibility of germination (particularly for therophytes) has been investigated for different species by many scientists (Symonides 1989; Fenner & Thompson 2005). Many factors have an influence on germination, such as soil temperature, moisture level, the impact of the surrounding plant communities, microbes or fungi (Rees & Long 1992; Egley 1995; Fenner & Thompson 2005). Observations of seed dormancy and germination behaviour of the genus *Euphrasia* have been made, but only with regard to seeds collected from nature and sowed in greenhouses, gardens, pots or Petri dishes (Yeo 1961, 1964; Liebst & Schneller 2008). Periodicity of populations in the natural, local area was first observed during the current study. This was also the first time that the spe-

Figure 1 – Euphrasia picta *Wimm. in the Tatra National Park. © E. Posz*

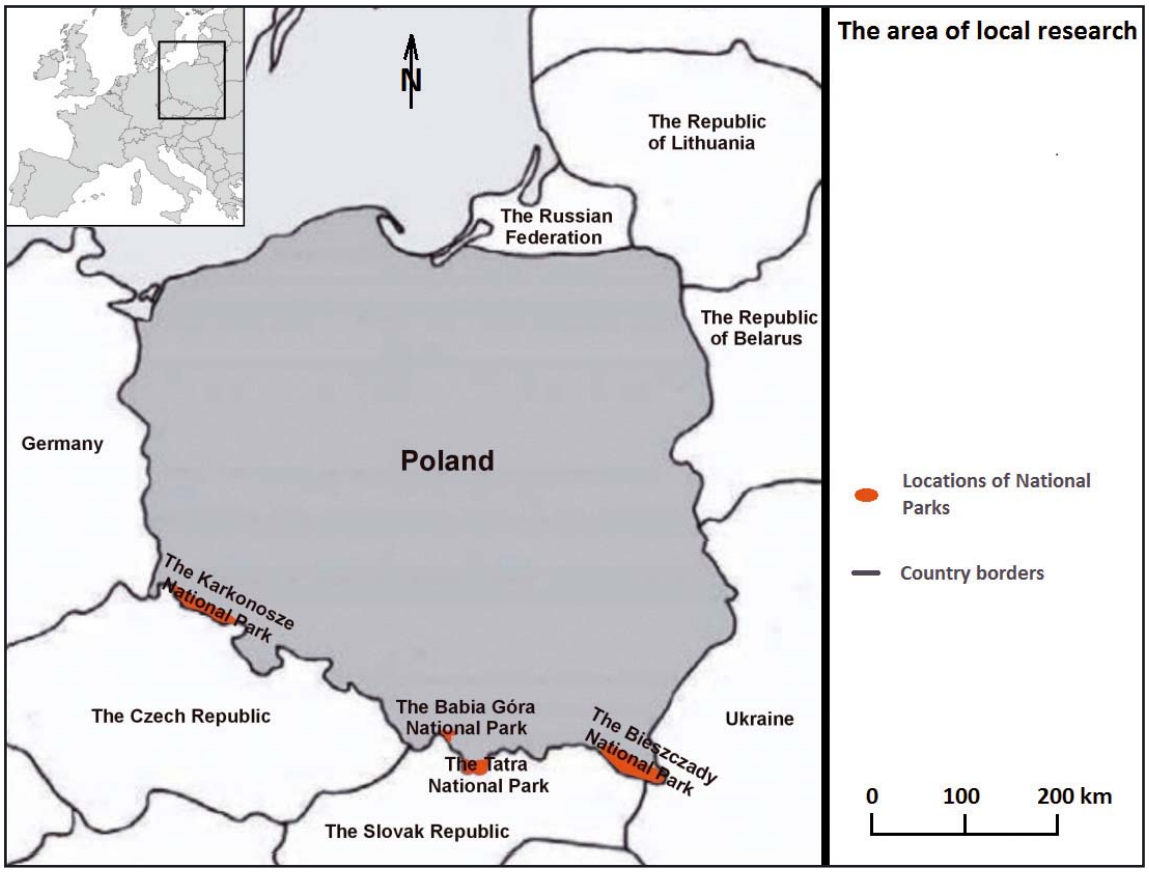

Figure 2 – The areas of local research: protected areas in the Karkonosze National Park, the Tatra National Park, the Babia Góra National Park, the Bieszczady National Park. Prepared by E. Posz.

cies had been systematically monitored. Furthermore, the study demonstrated that dormancy (i. e. the seeds lying in the soil, and the plant not appearing in a locality) may last for several years.

The aim of the monitoring programme was to determine whether such significant fluctuations in population numbers, including the absence of the plant from a locality, are an isolated anomaly, or whether they occur regularly and are part of the eyebright's survival strategy. The research question was: Does the periodicity phenomenon affect our understanding of this genus? The study also looked at the duration and frequency of these dormant periods, as well as the number of the plants, and whether they flowered and set fruits when they emerged at a locality after a period of absence.

Two species *E. picta* and *E. minima*, especially valuable botanically in Poland, were studied. These are, however, typically highland species, and in Poland they appear only within a small distribution range and not in great numbers. As the localities at which these species grow occur within national parks, the species are not under special protection in Poland. They are, however, recognized as a valuable part of the ecosystem and appear on Polish regional lists of rare and endangered plants (Pender 2003).

E. picta is an exceptionally rare species in Poland, confirmed in recent years only at a few sites in the Tatra and Bieszczady Mountain ranges. Due to changes in the forest management of the areas where the species is found, the localities have deteriorated, and the species is being pushed out by others. It is thus essential to discover whether the species is going extinct, or whether the absence of the plant at the locality is a temporary natural phenomenon.

E. minima is a species which has been confirmed during the on-going multi-year study at numerous sites in the Tatras, at many of which, however, it appears irregularly, with breaks of several years.

Materials and methods

Taxonomical studies and local research on *Euphrasia* species have been made in the Polish part of the Carpathians and the Sudetes since 2001 (Posz 2014). In addition, some sites of *E. picta* and *E. minima* have been regularly monitored in the Karkonosze, the Bieszczady, the Tatras and on Mt Babia Góra (Figure 2). The areas of local research are protected areas: the Karkonosze National Park (NP), Tatra NP, Babia Góra NP and Bieszczady NP.

Monitoring of the changes in the abundance and disappearance of populations was carried out in the Tatras, the Bieszczady and on Mt Babia Góra (in the Carpathians) from 2002 to 2015, and from 2008 to 2016 in the Karkonosze (the Sudetes). It was conducted every year in late July / early August. Before late

Table 1 – Monitoring of E. minima *in the Tatras: H: high abundance of plants (more than 500 individuals); –: the monitoring was not conducted at this site in this year (in the section* Current monitoring*), or documentation for the site was not found in herbarium material during research (in the section* Herbarium data*); X: the site was provided by Herbarium material.*

No.	Locality	Herbarium data						Current monitoring						
		Kulczyński 1875 (KRAM 185911)	Kulczyński 1875 (KRAM 185982)	Wrześniowski 1886 (ZAMU MT 826)	Wiśniewski 1923 (WA 018265)	Jasiewicz 1951 (KRAM 434725)	Pawlus & Jasiewicz 1986 (KRAM 453093)	Ewa Posz 2002	Ewa Posz 2003	Ewa Posz 2004	Ewa Posz 2008	Ewa Posz 2012	Ewa Posz 2014	Ewa Posz 2015
1.	Morskie Oko, nad stawem (the Sea Eye Lake, near the lake)	X						0	0	14	8	0	0	0
2.	Morskie Oko, Półwysep Miłości (the Sea Eye Lake, the Peninsula of love)	–	–	–	–	–	–	18	0	11	8	15	47	38
3.	Dolina Jaworzynki, skałki (the Jaworzynka Valley)					X		0	H	87	H	15	123	190
4.	Skupinów Upłaz (the Skupniów Upłaz)			X				0	67	15	0	25	150	43
5.	Ciemniak (Mt Ciemniak)				X			0	0	H	0	79	–	H
6.	Dolina Małej Łąki (the Little Meadow Valley)		X					0	0	15	267	0	157	45
7.	Przełęcz Między Kopami, Wielka Kopa Królowa (the Pass between the Kopas)	–	–	–	–	–	–	0	65	19	187	26	522	H
8.	Przysłop Miętusi, między Przysłopem a Kobylarzem (Mt Przysłop Miętusi, between Mt Przysłop and Mt Kobylarz)						X	0	0	18	6	0	8	0
9.	Sucha Dolina obok Przełęczy Liliowe (the Sucha Valley near the Liliowe Pass)	–	–	–	–	–	–	0	0	57	14	0	0	4
10.	Przełęcz Liliowe (the Liliowe Pass)	–	–	–	–	–	–	3	0	16	3	0	–	7
11.	Kopa Kondracka (Mt Kopa Kondracka)	–	–	–	–	–	–	0	0	9	0	16	–	28
12.	Małołączniak (Mt Małołączniak)	–	–	–	–	–	–	0	H	47	0	H	–	H
13.	Hala Gąsienicowa, skałki k. Murowańca (Gąsienicowa Hall Mountain, rocks near the Murowaniec shelter)	–	–	–	–	–	–	0	68	26	H	78	180	0
14.	Krzesanica (Mt Krzesanica)	–	–	–	–	–	–	0	0	H	0	65	–	H
15.	Chuda Turnia, Ciemniak (the Skinny Crag, Mt Ciemniak)	–	–	–	–	–	–	0	16	0	5	H	–	H

July, in cooler years in the higher reaches of the Tatras, the plants often still do not have fully developed seeds and capsules. On the other hand, in late August, frosts or even snowfalls often occur. The experiences of field studies show that eyebrights are sensitive to sudden changes of weather.

A modified version of the generally accepted method of species population monitoring was applied, as recommended by the Polish Environmental Protection Inspectorate and the Institute of Environmental Protection of the Polish Academy of Sciences for protected, endangered and rare species (Perzanowska 2010). This method is used successfully in the monitoring of 54 other vascular plants classified for monitoring as part of the Natura 2000 programme (Perzanowska 2010, 2012a, 2012b).

Studies were conducted at 14 sites for *E. picta* (Mt Babia Góra, the Bieszczady, the Tatras) and at 17 sites for *E. minima* (Mt Babia Góra, the Karkonosze, the Tatras). The observations were carried out in order to confirm the presence of a *Euphrasia* population in a given locality, to determine the population's abundance (counting of individuals), and to analyse the condition of individual plants (checking whether plants had flowered and set fruit capsules). In addition, photographic documentation of the sites was carried out every year. Plants collected from these localities at the beginning of the research for the purpose of species identification were deposited in the herbarium of the Institute of Botany, Jagiellonian University in Kraków (Posz 2014; Proszkiewicz 2006).

Historical data pertaining to some localities were gained from research (2001–2013) into the collections of a total of 30 herbaria (Mirek et al. 1997; Thiers [continuously updated]). The herbaria referred to are: Herbarium of Anna and Jan Kornasiowie in Cracow (AJK); Forest Research Institute in Białowieża (BIL); Białowieża Geobotanical Station (BSG); Technical-Agriculture Academy in Bydgoszcz (BYDG); Medical University of Gdańsk (GDMA); Jagiellonian University in Cracow (KRA); Polish Academy of Sciences – Institute of Botany in Cracow (KRAM); University of Agriculture in Cracow – Department of Forest Biodiversity (KRFB); Pedagogical University in Kielce (KTC); University of Silesia in Katowice (KTU); Maria Curie-Sklodowska University in Lublin (LBL); Lódz University (LOD); Upper Silesian Museum in Bytom (MGS); Teacher Training College in Olsztyn (OLTC); Medical Academy in Poznań – Department of Pharmaceutical Botany (PBMA); Adam Mickiewicz University in Poznań – herbarium of Department of Plant Taxonomy (POZ); Adam Mickiewicz

Table 2 – Monitoring of E. minima *in the Karkonosze Mountains (for the abbreviations, see Table 1).*

No.	Locality	Historical data				Current monitoring						
		Schube 1896 (SCHUBE 1897)	Sokołowski 1955 (BIL 423136)	Kusiak 1986 (KRAM 423140)	Kwiatkowski 1997 (KWIATKOWSKI 1998)	Ewa Posz 2008	Ewa Posz 2010	Ewa Posz 2011	Ewa Posz 2013	Ewa Posz 2014	Ewa Posz 2015	Ewa Posz 2016
1.	Mały Śnieżny Kocioł (the Small Snowy Kettle)	X	X	X	X	112	177	160	271	56	0	24
2.	Równia pod Śnieżką (the plateau under Mt Śnieżka)	–	–	–	–	H	H	H	H	H	H	H

University in Poznań – herbarium of The Natural Collections Faculty (POZG); Agricultural Academy in Poznań (POZNB); Roztocze NP in Zwierzyniec (RPNH); Teachers College in Słupsk (SLTC); Medical University of Silesia in Katowice (SOSN); University of Szczecin (SZUB); Nicolaus Copernicus University in Toruń (TRN); Gdansk University (UGDA); University of Warsaw (WA); Warsaw Agriculture University (WAUF); University of Podlasie in Siedlce (WSRP); Wrocław University (WRSL); Tytus Chałubiński Tatra Museum in Zakopane (ZAMU); Polish Academy of Sciences – Institute of Nature Conservation in Zakopane (ZTS).

Results

Studies on the distribution of *E. minima* in the Tatras carried out in 2002 and 2003 rendered few results (Table 1). Only a few localities for this species were discovered, despite the fact that herbarium collections (KRA, KRAM) contain a considerable number of sheets for this taxon. However, in 2004, there was a mass occurrence of this species on mountain pastures, rocks and even at the sides of trails. Specimens were also collected from sites documented in herbarium collections, although no representatives of *E. minima* were found there before 2004, despite careful field studies. In the following vegetation seasons, frequency in different localities varied: some populations disappeared, while some were continuously present, in spite of wide fluctuations in their abundance.

E. minima was found only at one site in the Karkonosze (Table 2), on a basalt dyke in Mały Śnieżny Kocioł (the Small Snowy Kettle) which was first described in the 19th century by Schube (1897). The next locality of the species (two populations) to be discovered, in 2008, was on Równia pod Śnieżką (the Plateau under Mt Śnieżka) (Posz 2010), and in 2014 yet another population was found, 300 m from the Równia pod Śnieżką one, between Mt Kopa and Równia pod Śnieżką. In 2015, for the first time, no plants were recorded in Mały Śnieżny Kocioł, although in 2014 their abundance there was relatively high. Plants were observed in 2016, but the population was not numerous.

Changes in the population abundance and even the disappearance of some of them were also observed for another mountain taxon – *E. picta*. In the Tatras (Table 3), a large, stable population confirmed by herbarium collections (KRA, KRAM) is located on Mt Sarnia Skała (the Deer Rock Mt), while the population

Table 3 – Monitoring of E. picta *in the Tatras (for the abbreviations, see Table 1).*

No.	Locality	Historical data								Current monitoring						
		Jasiewicz 1953 (KRAM 423147)	Jasiewicz 1953 (KRAM 423128)	Mądalski 1965 (KRAM 27958)	Jasiewicz 1966 (KRAM 440517)	Pawlus 1981 (KRM 450977)	Oklejewicz 1975 (zbiory własne)	Czeczott ? (KRAM 254061)	? 1926 (KRAM 334970)	Ewa Posz 2002	Ewa Posz 2003	Ewa Posz 2004	Ewa Posz 2008	Ewa Posz 2012	Ewa Posz 2014	Ewa Posz 2015
1.	Sarnia Skała (Mt Sarnia Skała)	X		X	X	X				0	0	0	21	15	H	H
2.	Gęsia Szyja (Mt Gęsia Szyja)	–	–	–	–	–	–	–	–	0	3	0	17	6	H	H
3.	Droga nad Reglami (the road above the Regles)	–	–	–	–	–	–	–	–	0	25	43	0	–	64	54
4.	Droga nad Reglami, okolice Doliny Białego (the road above the Regles, the Białego Valley)						X			0	4	0	0	0	H	25
5.	Dolina Strążyska, wylot (outlet of the Strążyska Valley)								X	0	0	0	9	0	0	0
6.	Dolina Kościeliska, okolice Hali Smytniej (the Kościeliska Valley, near the Hala Smytnia)		X					X		0	16	0	5	0	0	0
7.	Polana Waksmundzka (the Waksmundzka clearing)	–	–	–	–	–	–	–	–	0	0	9	0	3	5	0

Table 4 – Monitoring of E. picta *in the Bieszczady (for the abbreviations, see Table 1).*

No.	Locality	Historical data							Current monitoring						
		Jasiewicz 1954 (KRAM 423136)	Jasiewicz 1954 (KRAM 423136)	Jasiewicz 1954 (KRAM 423136)	Jasiewicz 1956 (KRAM 423146)	Jasiewicz 1960 (KRAM 423142)	Jasiewicz 1968 (KRAM 423125)	Zemanek & Winnicki 1993–1997 (Zemanek & Winnicki 1999)	Ewa Posz 2002	Ewa Posz 2003	Ewa Posz 2004	Ewa Posz 2008	Ewa Posz 2012	Ewa Posz 2014	Ewa Posz 2015
1.	Tarnica, szczyt (Mt Tarnica, the peak)			X					H	0	0	0	0	0	0
2.	Tarnica, skałki poniżej szczytu (Mt Tarnica, rocks below the peak)	–	–	–	–	–	–	–	0	3	0	179	6	89	314
3.	Tarnica, w drodze na szczyt (Mt Tarnica, in the path on the peak)	–	–	–	–	–	–	–	–	–	–	–	–	127	253
4.	Bukowe Berdo (the Bukowe Berdo)					X		X	8	0	0	0	5	0	0
5.	Krzemień (Mt Krzemień)	X			X			X	0	0	0	0	0	0	0
6.	Mała Rawka (Mt Mała Rawka)						X	X	H	0	0	0	0	0	0
7.	Smerek (Mt Smerek)		X						0	0	0	0	0	0	0

in the locality of *Droga nad Reglami* (the road above the Regles) appears and disappears irregularly. Monitoring carried out in the Bieszczady (Table 4) in 2002–2015 reported changes in the sites on Mt Tarnica and Bukowe Berdo (the Bukowe Berdo). The studies did not confirm many localities that had been documented in the herbarium collections (KRAM) of Jasiewicz (from the 1950s and 1960s) or Zemanek and Winnicki (1999). Mt Tarnica, the highest mountain of the Bieszczady, is a good locality to study population changes. In 2002, a large population of *E. picta* was found at the summit, below the viewing platform. During the following years (2003–2015), no plant was found at this locality. In 2003, a new population of the species was discovered on rocks, at a different site, in the northwestern part of the summit. The plants at this site were monitored constantly from 2003 to 2015, and noted almost every year. Another population, located slightly lower, midway between the pass and the summit, was discovered in 2014 and confirmed in 2015.

The occurrence of both *E. minima* and *E. picta* on Mt Babia Góra is well documented in herbarium collections (AJK, KRA, KRAM, MGS, WA). However, none of these sites was confirmed by monitoring carried out in 2003–2015.

Discussion and conclusions

Monitoring indicated that huge changes in plant numbers, including the total absence of the species from a locality is a normal phenomenon for highland eyebrights. These dormant periods, when no single plant of the species is observed at a locality, may be quite long, lasting for several years. It has been shown that the condition of the plants on reappearance is very good, i. e. they flower profusely and form capsules.

The fact that many of the populations found by Zemanek and Winnicki (1999) in Bieszczady cannot currently be confirmed may be associated not only with periodicity but also with natural succession in high mountain pastures caused by altered land use and the abandoning of pastures.

Periodicity is most probably connected with the creation of soil seed banks by *Euphrasia* species (Liebst & Schneller 2008), which is associated with the annual life cycle. Many years' dormancy of seeds in the soil was observed earlier, during their experimental cultivation from host plants in pots, greenhouses and gardens (Vitek 1998; Wilkins 1963; Yeo 1964; Liebst & Schneller 2008). In the high-mountain species under study, *E. minima* and *E. salisburgensis* (Liebst & Schneller 2008), the dormancy period lasted ca. three years, while in the low-land species *E. stricta* D. Wolff. ex F. Lehm. seed germination was observed up to fiveyears after sowing (Vitek 1998).

Knowledge about the periodicity phenomenon as seen in relation to the eyebright has a special significance in the process of estimating environmental resources in protected areas (for example NPs or *Nature 2000* areas), as described in the European *Habitats Directive*. So far, periodicity has not been taken into account in studies of the distribution of eyebright species in a defined area. Consequently, in order to gain a fuller and more accurate understanding of *Euphrasia* distribution, studies of the same area should be conducted continuously for at least four to five years. Floristic 1- or 2-year studies are often insufficient. Wide fluctuations of population abundance, and sometimes population disappearance for several years, can be a cause of incorrect evaluation of the population's condition and, consequently, the species' status in a given area. Excessive tourism and natural rock erosion of the habitat are usually suggested as the main factors causing a drastic drop or fluctuation in a population. They were, for example, listed in a case of *E. minima* evaluation for the Karkonoski Park Narodowy (Kwiatkowski 1998; Pender 2003; Wojtuń et al. 2003; Żołnierz et al. 2004). For the genus *Euphrasia*, however, periodicity of occurrence seems to be just as important a factor.

Faced with phenomena that are so difficult to interpret such as the disappearance of eyebright localities within the area studied, knowledge about their ecology and monitoring of their numbers may allow appropriate measures to be taken to protect the species. One such measure is the Jagniątków Living Gene Bank for the protection of the most precious species of flora of the Karkonosze NP (Jagniątków Living Gene Bank, The Karkonsze NP [continuously updated]), a programme which has been running for many years, co-financed by the European Union, and intended to protect and increase the gene pool of different taxa by vegetative and generative reproduction. One species covered by this programme is a species described in this article, *Euphrasia minima*. The question of which factor or series of factors directly influences the duration of eyebrights' seed dormancy, which may be quite prolonged, and the fluctuations of population abundance, remains open.

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