The Extinction of Terrestrial Orchids in Europe: Does Disappearance of *Cephalanthera* Rich., 1817 (Orchidaceae, Neottieae) Species Show Pattern Consistent with the Elevation Gradient?

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Abstract: Three species of genus *Cephalanthera*, i.e. *C. damasonium* (Mill.) Druce, 1906, *C. longifolia* (L.) Fritsch 1888, and *C. rubra* (L.) Rich. 1817 grow naturally in Poland. In different regions of Poland the species are characterized as critically endangered which face the danger of extinction. The aim of this study was to find if the decline of *Cephalanthera* spp. populations shows any pattern consistent with the elevation gradient. We used occurrence data covering the period from 1830s to present, to detect any shifts of altitudinal range among three periods: before 1945, 1946-1990 and after 1990. The shifts were analyzed with application of Kruskal-Wallis non-parametric test and post-hoc multiple comparisons. The analysis revealed that only significant altitudinal shifts were detected for *C. rubra* and *C. longifolia* between the first and the second period. We conclude that the decline of *Cephalanthera* species cannot be attributed to global change (climate warming or nitrogen deposition) as the shift took place in the first half of the 20th century. We believe that the species decline should rather be explained by changes in land use, including alteration of deciduous forests into coniferous monocultures, as well as by intensification of agriculture.

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1. Introduction

Orchid species have continued to decline dramatically during last decades (Seaton et al., 2010). Orchids decline is caused by land use change, climate change, tourism, limited geographical range, habitat loss, landscape fragmentation and unsustainable harvest for the orchid trade (Dixon et al., 2003; Prietzel et al., 2008; Liu et al., 2010; Ballantyne and Pickering, 2011; Paul et al., 2013). Better understanding of the phenomena referring to particular taxa may improve species conservation at regional scale.

The genus *Cephalanthera* is considered a primitive type of the monoandrous orchids with respect to vegetative structure, morphology and anatomy of flower and inflorescence and the type of pollination. It is mostly a Eurasian genus, including species native to Asia ranging from the Caucasus to Japan. The Chinese species *C. gracilis* was only described in 2002 (Chen and Zhu, 2002). The only species found in North America is *C. austiniae*. The genus presently contains 15 species (Delforge, 2006), in Europe it includes seven species. The European representatives of the genus can be divided in two groups, hypochile either with or without a spur. All species of *Cephalanthera* produce no nectar and are deceit flowers. This genus comprises allogamy or autogamy, sometimes even cleistogamy species (Delforge, 2006).

Only three species of *Cephalanthera* occur naturally in Poland, i.e. *C. damasonium* (Mill.) Druce, 1906, *C. longifolia* (L.) Fritsch 1888, and *C. rubra* (L.) Rich. 1817. They are rhizomatous (clonal) plants, growing in shadowy broadleaved forests, mixed forests as well as, sporadically, in coniferous forests, on humus soils, moderately wet, acidic to neutral, and sometimes in calcium rich carbonate substrates (Delforge, 2006).

Field observation in some regions of Poland suggests a link between the threat status and the elevational shifts of the population range. A shift in altitudinal range of flowering plant species is often reported in present ecological studies. In most cases, the shift is attributed to climate change, which increases upper limits of altitudinal zones in mountain areas (Grabherr et al., 1994; Pauli et al., 2007; Holzinger et al., 2008; Kelly and Goulden, 2008; Lenoir et al., 2008; Vittoz et al., 2008; Chen et al., 2011). Some studies show that shifts in species ranges may be driven by other factors, e.g. change in land use or forest maturation (Gehrig-Fasel et al., 2007; Kammer et al., 2007; Bodin et al., 2013). Altitudinal shifts must be explained with great caution. Otherwise, one may come to a wrong conclusion from the observed dynamics of a species range.

Using GIS environment and species distribution data we ask: does the long-term decline in *Cephalanthera* spp. populations show a pattern consistent with the elevation gradient? The research is restricted to the area of Lower Silesia. This region has a long history of floristic inventories; the collection of the occurrence data of *Cephalanthera* spp. dates from 1830s to present, and most of the historical data can be localized with satisfactory precision.

2. Material and Methods

Study species

Three species of the genus *Cephalanthera* Rich., 1817, namely *C. damasonium* (Mill.) Druce, 1906, *C. longifolia* (L.) Fritsch 1888, and *C. rubra* (L.) Rich. 1817 growing naturally in Lower Silesia were investigated.

First species – Red Helleborine (*C. rubra*) is a very rare orchid, critically endangered in many countries, found in forests and on woodland edges, in scrubby grassland and forests, particularly rich beech forests and oak forests, up to 2000 m a.s.l. (Figure 1A). The specimens can be found in rather open spots within the woods, sometimes amongst tall grass, brambles and other undergrowth, alongside paths or in scrubby places and open banks (Harrap and Harrap, 2009). It occurs in Europe and Asia, from the Atlantic to the Caspian Sea, however it seems to prefer a continental climate. Red Helleborine occurs very widely in Europe, but has suffered a dramatic decline over the last 100 years. Many populations are so small that they are in imminent danger of extinction

Another investigated taxon – White Helleborine (*C. damasonium*) is a self-pollinating, rare cleistogamous species growing on mid-shade to shade, calcareous to slightly acidic substrates (Delforge, 2006). This orchid occurs in Europe and Asia, in deciduous forests, pine forests and grasslands, up to 1800 m a.s.l. (Figure 1B). It is usually easy to find in suitable habitats, although it often grows away from paths and tracks, in heavy shade in the depths of the forest (Harrap and Harrap, 2009).

Sword-leaved Helleborine (*C. longifolia*) is pollinated by insects, this species is attractive to the pollinators of *Cistus salvifolius* (Delforge 2006). It occurs in Europe and Asia in the temperate and sub-Mediterranean zones (Figure 1C). *C. longifolia* is a woodland orchid but its optimum habitat is the interface of woodland and grassy areas (Harrap and Harrap, 2009). This species usually grows in mid-shade, on moist, calcareous or decalcified substrates, on open grasslands, woodland edges, glades, also in sparse undergrowth, up to 2000 m a.s.l. (Delforge, 2006).

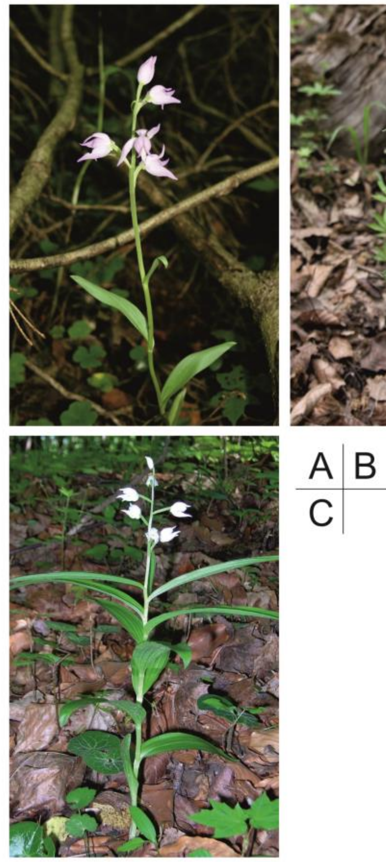

Figure 1. The habits of *Cephalanthera* spp. species analyzed. A - *Cephalanthera rubra*, B - *C. damasonium* and C - *C. longifolia*

Study area

Lower Silesia is the southwestern part of the historical and geographical region of Silesia [Upper Silesia is to the southeast of Poland (Central Europe)] and it is located mostly in the basin of the middle Oder River (Figure 2). The area is easy to study as it contains all altitudinal zones that can be found in Central Europe. The flora of Lower Silesia is specific and different for each five altitudinal zones, i.e. submountain zone (300-500 m), mountain deciduous forests zone (500-1000 m), mountain coniferous forests zone (1000-1250 m), subalpine zone (1250-1500 m) and alpine zone (> 1500 m). Moreover, Lower Silesia is a region of diversified land use. Intensively cultivated land or areas of high anthropogenic influence as well as naturally preserved vegetation complexes occur in all its altitudinal zones.

Figure 2. Location of the studied area

Data analyses

An extensive investigation of the distribution and ecology of all investigated species was conducted from 2011 to 2013, between May and June, on several populations differing in size, origin and location. A current distribution and population size have been studied, based on historic data from the turn of the 20th century (Fiek, 1881; Schube, 1903) (Figure 3). Occurrence data of *Cephalanthera* spp. form literature sources were georeferenced in GIS environment with the most possible precision, following best practices of Chapman and Wieczorek (2006). This data, together with present occurrences located with GPS, were used in our study as a point layer in GIS. We used a 30 m resolution digital elevation model to calculate the altitude value for each point of the species occurrence layer.

Altitudinal shifts were analyzed by comparing three periods: before 1945, 1946-1990 and after 1990. Differences of average altitude among these three periods were tested with the Kruskal-Wallis nonparametric test, as the data were not normally distributed. Furthermore, post-hoc multiple comparisons were used if the result of the Kruskal-Wallis test indicated a significant difference.

3. Results

The record numbers (data values) for the general frequency of the studied species in the analyzed region are as follows: *C. rubra* 52, *C. damasonium* 112 and *C. longifolia* 235.

All controlled species had a similar altitude range in lowland and foreland. Upper range limit of *C. rubra*, *C. damasonium* and *C. longifolia* is ca. 520 m a.s.l. (foreland), ca. 650 m a.s.l. (lower part of mountain deciduous forests) and ca. 910 m a.s.l. (upper part of mountain deciduous forests), respectively.

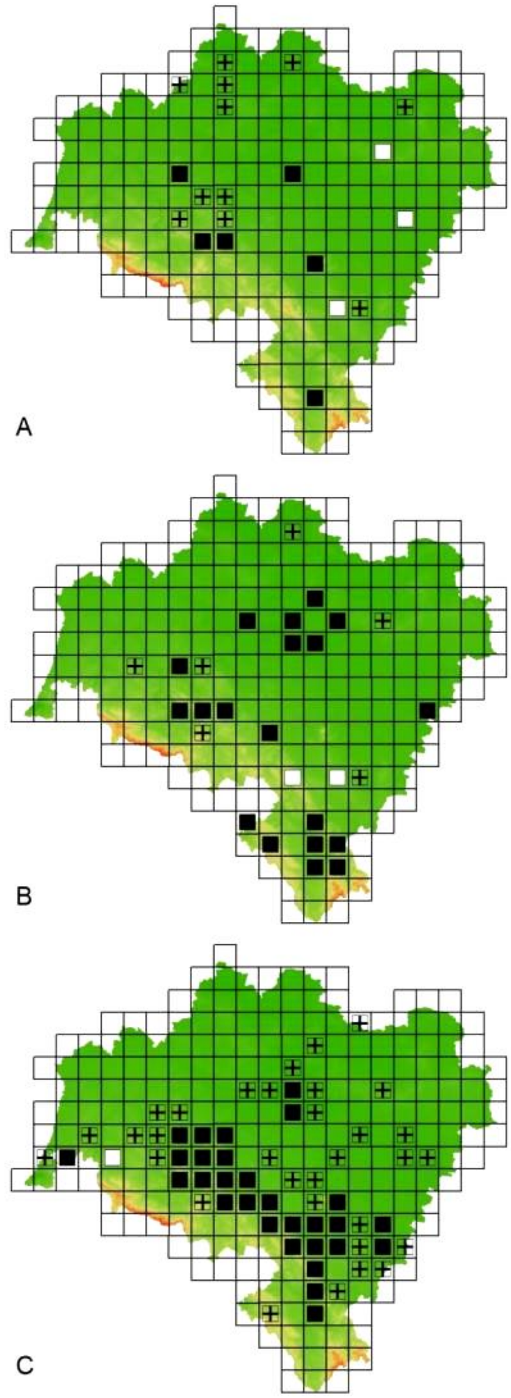

Figure 3. Distribution of the localities of *Cephalanthera* ssp. in Lower Silesia (SW Poland). A - *Cephalanthera rubra*, B - *C. damasonium* and C - *C. longifolia*. Descriptions: square with cross inside - locality recorded before 1945, white square - locality recorded in period 1946-1990, black square - locality recorded after 1990

Differences in average altitude among the three analyzed periods were significant for *C. rubra* and *C. longifolia* (*H*=8.354440, *P*= 0.0153 and *H*=8.905644, *P*=0.0116, respectively), while there was no significant difference detected for *C. damasonium* (*H*=0.4067709, *P*=0.8160). Furthermore, additional post-hoc tests revealed that only changes between the first and the second periods (≤ 1945 and 1946-1990) were significant. There has been no significant altitudinal shift since the second period analyzed (1946-1990) up to the present (Figure 4).

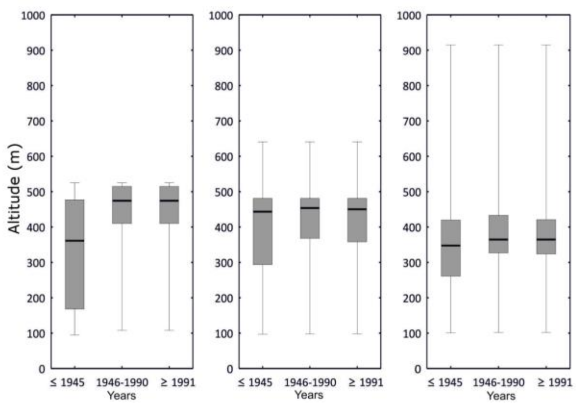

Figure 4. Change in the mean value of altitude for three endangered orchid species: *Cephalanthera rubra*, *C. damasonium* and *C. longifolia*. Only shifts between first and second periods for *C. rubra* and *C. longifolia* are statistically significant

4. Discussions

Our analysis revealed that the distribution of the three *Cephalanthera* species along the altitudinal gradient has changed within a timescale. Box plot (Figure 4) clearly shows the decline in lowland localities of all analyzed species. The mean value of altitudinal range changed significantly for *C. rubra* and *C. longifolia*. Surprisingly, a significant shift took place between the first and the second periods analyzed. It is contrary to our initial expectations, as we assumed that any meaningful shifts of species range occurred in the last decades and could be explained by global processes (e.g. climate change, nitrogen deposition). The results show that most of the occurrence data were reported at the turn of the 20th century, and the decline in *Cephalanthera* species began in the first quarter of the 20th century.

The loss of *Cephalanthera* sites cannot be explained by recent global changes of climate and we refer this process to the change of land use at the beginning of the 20th century. Most extensive complexes of deciduous forests were drastically altered into coniferous monocultures. Two most common conifers dominated forest plantations in Central Europe: Scots pine (*Pinus sylvestris*) at lowland sites and Norway spruce (*Picea abies*) in mountain environments. The magnitude of this alteration was much more extensive in lowland habitats of orchids while forest management in mountain forests, which developed on initial soils, was rather marginal. These disturbances led to a considerable increase in the acidity of soils, with long-term associated ramifications for biodiversity and subsequent land-uses (Nordborg and Olsson, 1999; Jönsson et al., 2003; Felton et al., 2010).

Beside alterations of forest structure, eutrophication of forests stands in agricultural landscape could markedly influence the decline of orchids in forest ecosystems. The supply of forest soils with nutrients is reflected by domination of nitrophilous shrubs (e.g. *Rubus* sp., *Sambucus nigra*) and an increase in nitrophilous field weeds (Schlüter et al., 1990). This phenomenon led to competitive exclusion and homogenization of forest herb layer.

An important issue in studies on orchids demography is to consider their access to pollinators. On the analysis of distribution maps of the studied *Cephalanthera* species in lowland of Lower Silesia we know that at least some of them grew in small forests bordering with cultivated lands, such as fields or meadows, which due to their floral plants abundance were willingly visited by insects. The intensification of agriculture, on the one hand, has resulted in a significant reduction of meadow size, followed by a more limited access of insects (pollinators) to the neighbouring forest populations of the *Cephalanthera* species. On the other hand, intensive farming has caused eutrophication of adjacent areas and promotion of competitive species.

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References

1. Ballantyne M, Pickering C. Ecotourism as a threatening process for wild orchids. Journal of Ecotourism 2011;11:34-47.
2. Bodin J, Badeau V, Bruno E., Cluzeau C, Moisselin JM, Walther GR, Dupouey JL. Shifts

of forest species along an elevational gradient in Southeast France: climate change or stand maturation? Journal of Vegetation Science 2013;24:269-283.

3. Chapman AD, Wieczorek J. Guide to Best Practices for Georeferencing. Global Biodiversity Information Facility, Copenhagen. 2006;1-80.
4. Chen SC, Zhu GH. *Cephalanthera gracilis* (Orchidaceae), a new species from China. Acta Bot. Yunnan. 2002;24(5):600-602.
5. Chen IC, Hill JK, Ohlemüller R, Roy DB, Thomas CD. Rapid Range Shifts of Species Associated with High Levels of Climate Warming. Science 2011;333:1024-1026.
6. Delforge P. Orchids of Europe, North Africa and the Middle East. Timber Press Inc., Oregon, USA. 2006:1-640.
7. Dixon KW, Kell SP, Barrett RL, Cribb PJ. Orchid conservation. Natural History Publications (Borneo), Kota Kinabalu, Sabah. 2003:1-24.
8. Felton A, Lindbladh M, Brunet J, Fritz Ö. Replacing coniferous monocultures with mixed-species production stands: An assessment of the potential benefits for forest biodiversity in northern Europe. Forest Ecology and Management 2010;260:939-947.
9. Fiek E. Flora von Schlesien preussischen und österreichischen Antheils, enthaltend die wildwaschsenden, verwilderten und angebauten Phanerogamen und Gefäss-Cryptogamen. J.U. Kern’s Verl., Breslau, 1881:1-164.
10. Gehrig-Fasel J, Guisan A, Zimmermann NE. Tree line shifts in the Swiss Alps: Climate change or land abandonment? Journal of Vegetation Science 2007;18:571-582.
11. Grabherr G, Gottfried M, Pauli H. Climate effects on mountain plants. Nature 1994;369:448-448.
12. Harrap A, Harrap S. Orchids of Britain and Ireland: A Field and Site Guide Ebook. A&C Black. 2009:1-480.
13. Holzinger B, Hülber K, Camenisch M, Grabherr G. Changes in plant species richness over the last century in the eastern Swiss Alps: elevational gradient, bedrock effects and migration rates. Plant Ecology2008;195:179-196.
14. Jönsson U, Rosengren U, Thelin G, Nihlgård B. Acidification-induced chemical changes in coniferous forest soils in southern Sweden 1988-1999. Environmental Pollution 2003;123:75-83.
15. Kelly AE, Goulden ML. Rapid shifts in plant distribution with recent climate change. Proceedings of the National Academy of Sciences 2008;105:11823-11826.
16. Lenoir J, Gégout JC, Marquet PA, De Ruffray P, Brisse HA. Significant Upward Shift in Plant Species Optimum Elevation During the 20th Century. Science 2008;320:1768-1771.
17. Liu H, Feng CL, Luo YB, Chen BS, Wang ZS, Gu HY. Potential Challenges of Climate Change to Orchid Conservation in a Wild Orchid Hotspot in Southwestern China. The Botanical Review 2010;76:174-192.
18. Nordborg F, Olsson S. Changes in soil mineralogy and exchangeable cation pools in stands of Norway spruce planted on former pasture land. Plant and Soil 1999;207:219-229.
19. Paul J, Budd C, Freeland J. Conservation genetics of an endangered orchid in eastern Canada. Conservation Genetics 2013;14:195-204.
20. Pauli H, Gottfried M, Reiter K, Klettner C, Grabherr G. Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994-2004) at the GLORIA* master site Schrankogel, Tyrol, Austria. Global Change Biology 2007;13:147-156.
21. Prietzel J, Rehfuess K, Stetter U, Pretzsch H. Changes of soil chemistry, stand nutrition, and stand growth at two Scots pine (*Pinus sylvestris* L.) sites in Central Europe during 40 years after fertilization, liming, and lupine introduction. European Journal of Forest Research 2008;127:43-61.
22. Schube Th. Die Verbreitung der Gefässpflanzen in Schlesienpreußischen und österreichischen Anteils. R. Nischowsky Verl., Breslau. 1903:1-361.
23. Schlüter H, Böttcher W, Bastian O. Vegetation change caused by land-use intensification - examples from the Hilly Country of Saxony. Geo Journal 1990;22:167-174.
24. Seaton P, Hu H, Perner H, Pritchard H. Ex Situ Conservation of Orchids in a Warming World. The Botanical Review 2010;76:193-203.
25. Vittoz P, Bodin J, Ungricht S, Burga CA, Walther GR. One century of vegetation change on Isla Persa, a nunatak in the Bernina massif in the Swiss Alps. Journal of Vegetation Science 2008;19:671-680.

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