

## ORCHIDACEAE IN THE ANTHROPOGENIC LANDSCAPE OF CENTRAL POLAND: DIVERSITY, EXTINCTION AND CONSERVATION PERSPECTIVES

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**Abstract** - Orchidaceae are considered one of the largest and most endangered plant families worldwide. We analyzed the status of conservation of orchid sites in Central Poland, which serves as a model area for transformed environments in moderate climate. In the area under study, 26 orchid species from 54 taxa existing in Poland were reported, 17 of them with fewer than 20 localities, 59% of which have not been confirmed since 2000. Spatial analysis of all localities has shown that Central Poland exhibits considerable diversity as regards the incidence of Orchidaceae. It has been shown that contemporary protection methods have failed to prevent the demise of these species in forest, meadow and bog habitats, which incidentally comprised most of those whose localities have been unconfirmed since 2000.

**Key words:** orchids; protected species; protection of habitats; floristic value; Central Poland

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### INTRODUCTION

Orchidaceae are the largest of flowering plant families including almost 10% of all flowering plants and an estimated 20-30 thousand species (Atwood, 1986; Baumann et al., 2010; BUTTLER, 2000; Chase et al., 2003; Gamarra et al., 2010; Garay and Sweet, 1974; Gentry and Dodson 1987; Harrap A. and Harrap S. 2010; Pillon and Chase, 2007; Witting and Witting, 2007). Simultaneously, it is one of the most vulnerable plant groups (Arditti, 1967; Clemente, 2009; Dickson, 1990; Dressler, 1981; Ehlers et al., 2002; Light and MacConaili, 2006; Nigel et al., 2009; Pridgeon, 1996; Scotland and Wortley, 2003;). Drivers of rarity of orchids can be extrinsic or intrinsic. The ex-

tinction of many species of orchids results from the synergic effect of detrimental habitat changes and their complex biology (Swart and Dixon, 2009).

Orchidaceae are characterized by a long life span (up to 15 years), the reliance on compatible fungi for seed germination (Swarts and Dixon, 2009) and a highly specialized mechanism of insemination. Specific species have greatly individualized requirements as to the biotic and abiotic features of a site (McCormick et al., 2004; Rasmussen and Whigham, 2002; Zettler et al., 2004). The ever-increasing human impact on soil degradation and on moisture conditions, changes in the floristic composition of plant communities and consequently the species structure of

pollinating insects in the context of the demanding biology are the main causes of the orchid's extinction (Clemente, 2009).

Abundance of Orchidaceae is not uniformly distributed globally but the largest number of species can be found in tropical and subtropical climates (Cribb et al., 2003; Cribb and Govaerts, 2005; Kurzweil, 1993; Pridgeon, 1996; Szlachetko, 2010, 1995). The number of European orchids is given to be approximately 230 (Delforge, 2006; Dlessler, 1993; Hagsater et al., 1996). Within European lowlands, the spatial distribution of diversity of species has been severely influenced by centuries of human activity (Ellenberg, 1986). Most European orchids are rare or endangered (Delforge, 2006; Dlessler, 1993; Hagsater et al., 1996) and have thus come to be regarded as indicative taxa of the state of the habitat (Jalal, 2012; Kull et al., 2009; Swarts and Dixon, 2009). Based on the premise that even a slight change to environmental components (be it abiotic and biotic) can trigger orchid extinction (Adamowski, 2006; Wittig and Wittig, 2007), their current protection program has mainly focused on habitat conservation (Batty et al., 2006; Shibu et al., 2012). To retain the composition and function of a habitat often an active protective effort is demanded, e.g. in the case of meadow species it is important to continue extensive forms of management (Jakubowska -Gabara, 2009; Jalal, 2012).

In terms of landscape transformation, the region of Central Poland may be considered as representative of a large part of European lowlands. The landscape is mainly agricultural and urban, with only small patches of vegetation close to natural in their characteristics. The natural relics can be found mostly in 87 nature reserves constituting 0.4% of the total region area, 36 Natura 2000 special areas of conservation, constituting 2.9%, and 7 landscape parks covering 5.4% (Kurowski et al., 2009; Kurowski et al., 2013). To preserve orchid localities in Central Poland it is especially important to focus conservation efforts in habitats such as: i) peatlands – a habitat of *Epipactis palustris*, *Liparis loeselii*, *Orchis palustris* among others; ii) the broadleaved moist forest habi-

tats of *Neottia nidus-avis* and *Dactylorhiza fuchsii*; iii) the thermophilous forests supporting such species as *Cephalanthera rubra* and *Cypripedium calceolus*; and finally, iv) extensively managed meadows – the habitat of *Orchis militaris* and *Gymnadenia conopsea* (Jakubowska-Gabara et al., 2011).

Despite decades of floristic studies of Central Poland (Jakubowska-Gabara et al., 2011; Kurowski, 2009; Olaczek, 2012), there is lack of synthetic studies concerning the Orchidaceae family: its diversity, spatial distribution patterns of and state of conservation. We still need an ultimate answer to the question of whether the network of protective areas covers all local diversity centers for this plant family.

The aims of this study were to analyze: i) the diversity and distribution of orchids in Central Poland, ii) the extinction rate and threat level of Orchidaceae family, and iii) the distribution of key areas for regional diversity of this group of plants in comparison to general land use forms and actual nature conservation network.

## MATERIALS AND METHODS

### *Study area*

The study covered an area of 21 700 km<sup>2</sup> in Central Poland (Fig. 1). The northern and central parts of the area under study belong to the Central European Lowland, whereas its southern parts are located within the Polish Uplands (Kondracki, 2002). The lowlands have the characteristics of an old glacial landscape – remnants of the Warta and Odra glaciations. The landscape of the southern part of the region is transient between uplands and lowlands and is characterized by numerous Mesozoic limestone and sandstone outcrops. The potential natural vegetation of Central Poland are mainly linden-oak-hornbeam forests (alliance *Carpinion*), mixed pine-oak and pine forests (*Dicrano-Pinion*), thermophilous oak forests (*Potentillo-Quercion*) and with less share in area, silver fir and beech forests (*Galio-Abietion* and *Fagion*) (Matuszkiewicz, 2001).

Central Poland is a model area of middle European lowlands with severely transformed flora and natural habitats. It is a region with Poland's lowest percent of forest area at 20.9% (Kucharski, 2009; Kurowski, 2009), a large area of arable lands, quite densely populated with developed road infrastructure. One of the biggest European open-pit brown coal mines is located here.

#### *Species distribution data*

Between 2004 and 2014 the flora of Central Poland was intensively studied as part of the preparation of the Distribution Atlas of Vascular Plants in Central Poland (Jakubowska-Gabara et al., 2011) and Red Book of Plants of Lodz Voivodship (Olaczek, 2012). To achieve the aforementioned purposes the grid method was adopted following the methodology assumed for the country and region levels during the preparation of a national ATPOL grid (Jakubowska-Gabara et al., 2011; Zajac, 1978; Zielińska et al., 2010) (Fig. 1). The area under analysis was covered by a grid of squares with a code assigned to each, e.g. DE4824. The first two letters signify a square with the area of 100 x 100 km (read first vertically, next horizontally), the subsequent pair denote squares 10 x 10 km and 2 x 2 km (read first horizontally, then vertically) (Zielińska et al., 2010). The occurrence of a species in the primary square of the grid (2 x 2 km) was treated as one locality regardless of whether one or more populations have been found in it. The data as to the presence of Orchidaceae were taken from synthetic publications on the rare plants of Central Poland (Jakubowska et al., 2011; Olaczek, 2012) and the latest publications on Orchidaceae in that area (Kiedrzyński and Stefaniak, 2011; Stefaniak and Dąbrowska, 2013).

#### *Analysis of threat and extinction rates*

Orchid species have been divided into two groups depending on the number of localities: group A includes rare species with less than 20 localities; group B includes species with more than 20 localities. The localities of orchids from group A have been also historically verified and subdivided into those dis-

covered or confirmed since 2000 and those not confirmed.

An analysis of the degree of threat to orchids per mainly occupied habitats in Central Poland has been conducted. Each species has been assigned a predominant habitat type of its occurrence. Three ecological groups of orchids have been distinguished: plants occurring in forests (F), meadows (M) and peatlands (P), and the degree of threat to each group has been estimated.

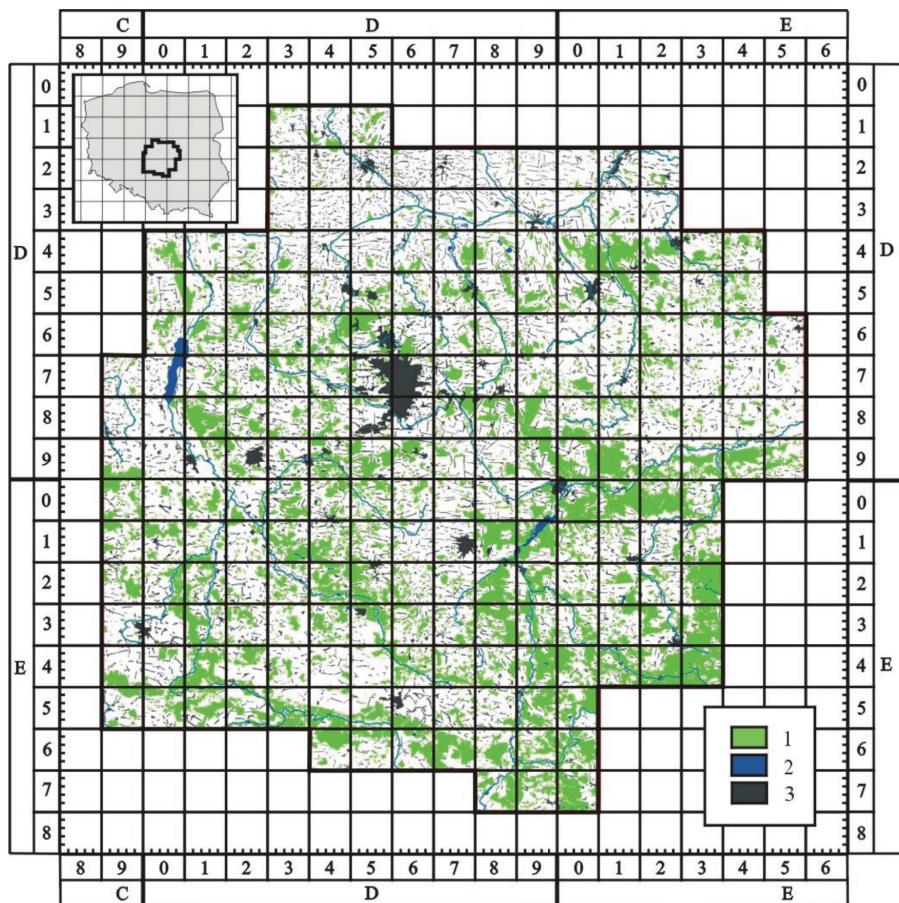
#### *Spatial pattern in species richness and rarity*

With a grid of 10 x 10 km-sized squares, maps indicating the distribution of the number of species as well as the values of indices – floristic value (FV) and floristic uniqueness (FU) – of particular squares were made. The floristic value index (FV) is a sum of rarity coefficients ( $I_r$ ) of species detected within a given primary square of the grid, while the rarity coefficient of a species was calculated according to the formula  $I_r = (N-n)/N$ , where  $N$  is the total number of squares sized 10 x 10 km and  $n$  is the number of squares in which the species occurs. Floristic uniqueness index (FU), on the other hand, is the quotient of the floristic value of a given square divided by the number of species within that square (Géhu, 1979).

#### *Analysis of correlation of orchids indexes to land form use and nature conservation network*

For each square sized 10 x 10 km it was established what area is under legal protection, the area of forest and the built-up area. Areas protected by law (reserves, NATURA 2000 sites and landscape parks, which represent the least transformed sites of Central Poland) were included in the study. Spatial analyses were performed in ArcMap 9.2 software (ESRI Inc. 1999-2008, Redlands, CA, USA).

We used Spearman's rank correlation coefficients to examine whether there exists a link between the surface area taken in each 10 x 10 km square by protected, forested and built-up areas and the number of



**Fig. 1.** The location of study area in Poland and in the square of the grid map: symbol of the square DE4824; 1 – forests; 2 – water reservoirs and rivers; 3 – built up areas.

species of A and B groups as well as FV and FU indices. Results were considered significant for  $p < 0.05$ .

Nomenclature of orchids according to Deleforge (2006).

## RESULTS

In Central Poland, 26 species of orchids belonging to 13 genera, the most numerous of which were *Dactylorhiza*, *Cephalanthera* and *Epipactis*, have been detected. Most of the species have been included in the Red Data Book of the region (Tab. 1).

Most orchids were represented with a limited number of localities. Among 90 localities of rare taxa

in the region (group A), only 41% have been confirmed since 2000. In the case of five of the species, no localities have been confirmed. There are only three species with the total number of localities confirmed or discovered since 2000. Among those, *Dactylorhiza sambucina* is the only species that has not been detected in the area.

The map with the localities of group A species (Fig. 2) represents the spatial distribution of contemporary and historical data for the most valuable species. In all the 5 425 2 x 2 km-sized squares, only 28 had group A orchid localities reported in 2000 or later. The largest number of unconfirmed localities, those with the highest probability of extinction, is to be found in the northern and central part of the re-

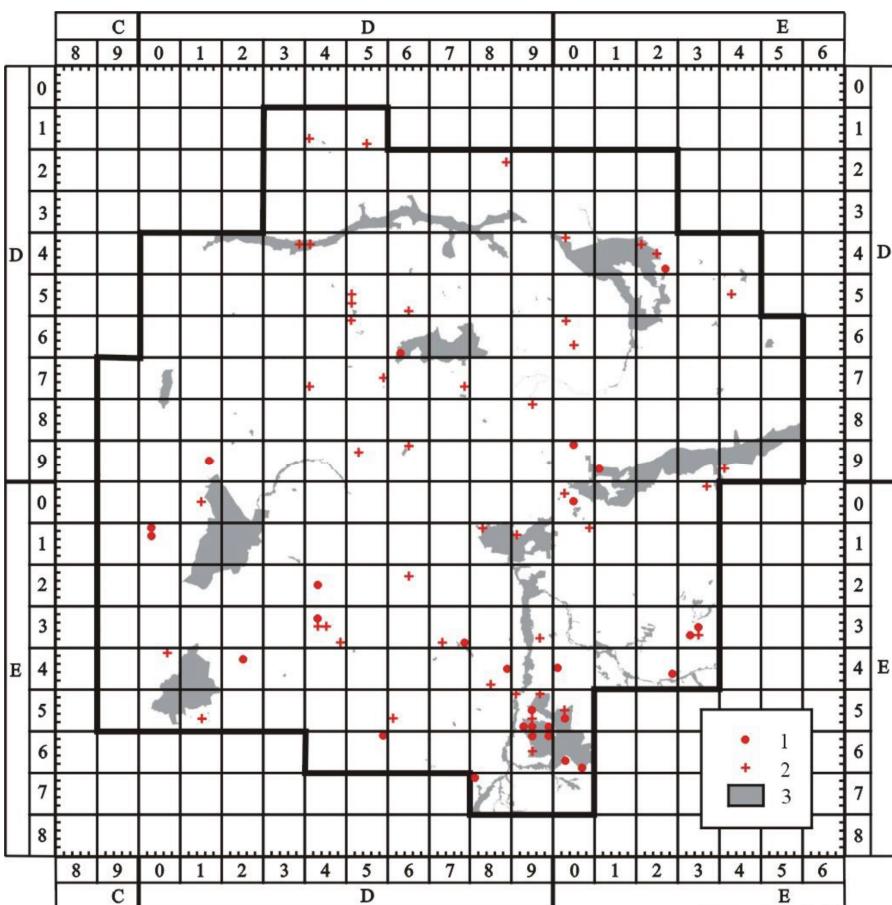
**Table 1.** Species of Orchidaceae family occurring in central Poland

Species	Main habitat in Central Poland	Red Data Book of Lodz Voivoship	Nr of localities (No. of squares 2 x 2 km)
<b>Group A</b> ( $\leq$ 20 localities)			
<i>Dactylorhiza sambucina</i> (L.) Soó	F		1
<i>Malaxis monophyllos</i> (L.) Sw.	P	EX	1
<i>Orchis coriophora</i> L.	M		1
<i>Corallorrhiza trifida</i> Chatelain	F	CR	2
<i>Cypripedium calceolus</i> L.	F	EN	2
<i>Epipactis purpurata</i> Sm.	F		2
<i>Orchis militaris</i> L.	M	EX	2
<i>Orchis palustris</i> Jacq.	P	EX	2
<i>Cephalanthera longifolia</i> (L.) Fritsch	F	CR	3
<i>Gymnadenia conopsea</i> (L.) R. Br	M	EX	3
<i>Goodyera repens</i> (L.) R. Br	F	CR	3
<i>Orchis morio</i> L.	M	EX	4
<i>Liparis loeselii</i> (L.) Rich	P	EN	6
<i>Platanthera chlorantha</i> (Custer) Rchb.	F	VU	11
<i>Epipactis atrorubens</i> (Hoffm.) Besser	F		13
<i>Cephalanthera damasonium</i> (Mill.) Druce	F	VU	17
<i>Cephalanthera rubra</i> (L.) Rich.	F	CR	17
<b>Group B</b> (21 – 100 localities)			
<i>Dactylorhiza fuchsii</i> (Druce) Soó	F		40
<i>Epipactis palustris</i> (L.) Crantz	P		44
<i>Neotia nidus-avis</i> (L.) Rich.	F		50
<i>Dactylorhiza incarnata</i> (L.) Soó	P		65
<i>Dactylorhiza maculata</i> (L.) Soó	F		78
<i>Listera ovata</i> (L.) R. Br.	F		88
<i>Platanthera bifolia</i> (L.) Rich	F		101
<i>Epipactis helleborine</i> (L.) Crantz	F		196
<i>Dactylorhiza majalis</i> (Rchb.) P.F. Hunt & Summerh.	M		319
Total			1071

**Abbreviations:** F – forests, P – peatland, M – meadows; EX – extinct, CR – critically endangered, EN – endangered, VU – vulnerable

gion. In the entire area, there are only 7 squares with more than one group A species. There is only one plot (DE5942) with an exceptional floristic richness, where as many as 4 group A species have been reported. Most localities confirmed since 2000 are situated within or adjacent to the areas under protection. In 37 such localities only 8 are outside the protected areas, including 5 localities of *Cephalanthera rubra*.

The regionally rare orchids (group A) lists 17 species, among which 10 are forest species (Table 3). Also among the more frequent 9 species (group B), forest species are predominant. Similar relationships are to be found between the number of localities rather than the number of species. Notably, the decrease of the number of group A localities has been detected for all three types of habitats, with the most

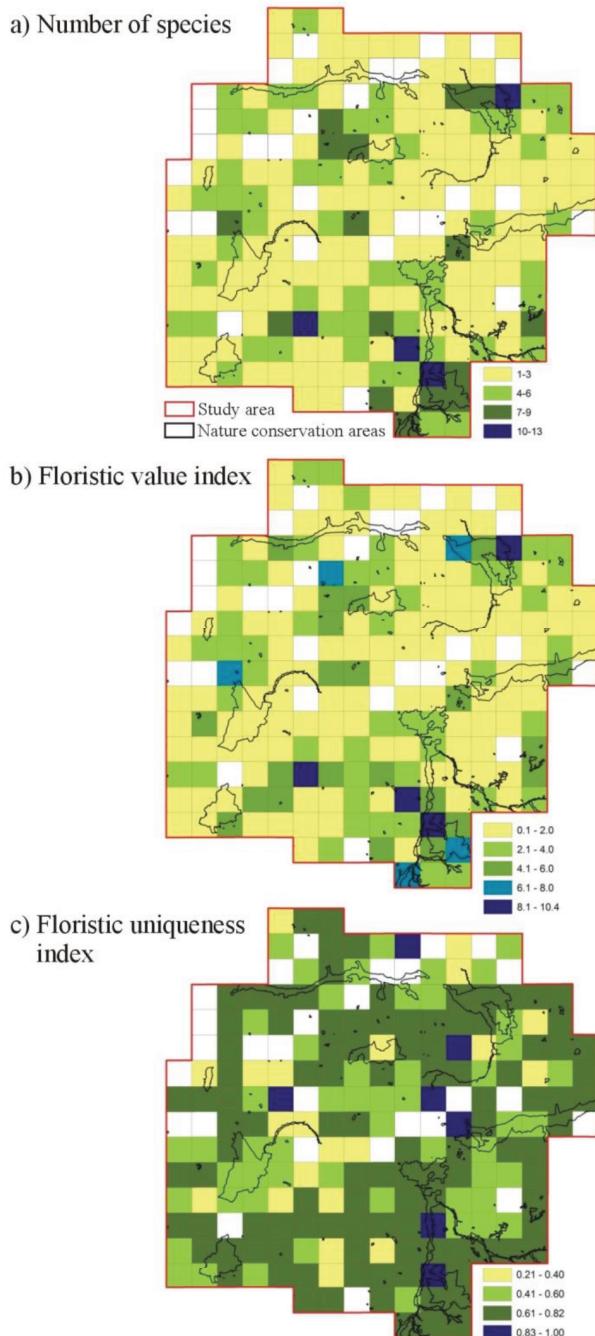


**Fig. 2.** Square grid map with the primary squares of 2 x 2 km representing localities of group A species set against protected areas in the form of reserves; NATURA 2000 sites and landscape parks; 1 – a site reported or confirmed in 2000 or later; 2 – a site reported before 2000 and unconfirmed later; only the localities whose position was established with the degree of accuracy allowing for them to be included in a grid square; 3 – protected area.

significant loss among the peatland and meadow species (Tab. 3).

The analysis of the distribution of number of species as well as FV and FU indices has pointed out a significant inconsistency in the occurrence of Orchidaceae in Central Poland (Fig. 3). The distribution of floristic value index is very similar to the distribution of species richness. It is to be noted, however, that not all the squares precious for the large number of orchids overlap with the squares precious for the rarity of the reported taxa as indicated by FU index (Fig. 3).

The analysis of correlation of the area occupied by protected, forest and built-up areas and the number of orchid species and FV and FU indices has not yielded any significant correlation (Table 4). Note-worthy, however, is that the positive values of the correlation index point to a relationship between the number of orchids, FV and, FU indices and the surface area of forest and the area under protection, whereas negative values of the correlation characterize the relationship between the aforementioned indices and built-up areas. Another interesting aspect is the high degree of correlation between the FV index and species richness and a much lower link between the index and FU index.



**Fig. 3.** Square grid map with 10 x 10 km for the number of species (a) and floristic value index (b) and floristic uniqueness index (c).

## DISCUSSION

In the entire territory of Poland 56 species of orchids are listed (Mirek et al., 2002; Szlachetko, 2010), all of them under strict protection (Decree of the Minister of Environment of 5 January 2012). On the territory of Central Poland, 26 species have been reported – almost half of the entire orchid flora of Poland. Two of the reported taxa (*Cypripedium calceolus* and *Liparis loeselii*) are significant considering the European network of protected sites – NATURA 2000. In Central Poland, orchids constitute as much as 18.05% of all species of protected plants (144 species in total) (Jakubowska-Gabara et al., 2009). Thirteen of the reported species were included in the regional Red Book (Olaczek, 2012), five of which are assigned the extinct status (EX). The summary of the knowledge about orchids in Central Poland offered by the paper indicates that the process of extinction of the plant family is more intense over the area under study than other publications have presented. Besides the species listed by the Red Book, *Epipactis purpurata* and *Orchis coriophora* should be considered as extinct in the area, and among those critically endangered are *Dactylorhiza sambucina* and *Epipactis atrorubens*.

Orchids of Central Poland do not constitute a uniform group with regard to their endangered status. Some of the rare species have in all probability become extinct, although taking into account their ephemeral incidence it cannot be stated with all certainty. Among 26 of the reported species, 17 are represented at fewer than 20 localities and 59% of these have not been confirmed since 2000 (Table 2, Fig. 2). Many of these are verging on extinction, especially those with only one locality reported since 2000: *Cephalanthera longifolia*, *Gymnadenia conopsea*, *Liparis loeselii* and the recently discovered in Central Poland *Dactylorhiza sambucina* (Stefaniak and Dąbrowska, 2013). The orchids that are characteristic for peatland and meadows are the group that has almost disappeared from Central Poland (Table 3). Among the five rare species (group A) whose localities have not been confirmed since 2000, two are peatland species (*Malaxis monophyllos*, *Orchis palus-*

**Table 2.** Historical analysis of the occurrence of rare orchid species (group A – with less than 20 localities in 2 x 2 km squares) in Central Poland; highlighted are the species with more than 80% of localities not confirmed since 2000.

Species	No. of localities confirmed or found from 2000	No. of localities not confirmed from 2000	Total no. of localities	% not confirmed localities
<i>Epipactis purpurata</i>	0	2	2	100.0
<i>Malaxis monophyllos</i>	0	1	1	100.0
<i>Orchis coriophora</i>	0	1	1	100.0
<i>Orchis militaris</i>	0	2	2	100.0
<i>Orchis palustris</i>	0	2	2	100.0
<i>Cephalanthera longifolia</i>	1	2	3	66.7
<i>Dactylorhiza sambucina</i>	1	0	1	0.0
<i>Gymnadenia conopsea</i>	1	2	3	66.7
<i>Liparis loeselii</i>	1	5	6	83.3
<i>Corallorrhiza trifida</i>	2	0	2	0.0
<i>Cypripedium calceolus</i>	2	0	2	0.0
<i>Goodyera repens</i>	2	2	4	50.0
<i>Orchis morio</i>	2	1	3	33.3
<i>Epipactis atrorubens</i>	3	14	17	82.4
<i>Platanthera chlorantha</i>	6	5	11	45.5
<i>Cephalanthera damasonium</i>	8	5	13	38.5
<i>Cephalatthera rubra</i>	8	9	17	52.9
total	37	53	90	58.9

*tris*) and the other two are meadow species (*Orchis coriophora*, *Orchis militaris*). Although the drop in the number of localities of orchids concerns each of the analyzed habitats, it is not the same for each group. In the group A forest species, the decrease has reached almost 54%, for meadow species the value is 70% and as much as 89% for peatland species (Table 3). The uniqueness of meadow habitats results from the fact that in Central Poland they are seminatural and their abandonment or intensification of management invariably leads to severe transformation of habitat conditions (Garcia, 1992; Kucharski, 1999). The peatland sites that disappeared because of peat extraction are now in danger of completely drying out. In Central Poland, similar to many parts of Poland, the ground water level is now lower than in the 19th and early 20th centuries (Lipiński, 2006).

However, in the area under analysis there exist taxa with localities in more than 100 squares of the 2 x 2 km grid. These are *Platanthera bifolia*, *Epipactis helleborine* and *Dactylorhiza majalis* (Table 1). In the case of *E. helleborine*, its population typically numbers many specimens that flower and fruit every year (Kiedrzyński and Stefaniak, 2011). Contrary to majority of Orchidaceae, *Epipactis helleborine* is a eurotypical species (Dickson, 1990) and is to be found in not only broadleaved forests but also ruderal habitats, such as roadsides, quarries and railways (Adamowski, 1996; Dickson, 1990; Kiedrzyński and Stefaniak, 2011; Stefaniak et al, 2011; Wittig and Wittig, 2007). The phenomenon of orchids occupying new disturbed habitats, which can be seen in Central Poland, is known also in other parts of the world. In tropical regions there are species called

**Table 3.** Number of localities and species of orchids in the studied habitat types

Preferred habitats	No. of species	No. of species from A group	No. of species from B group	No. of localities	No. of localities of species from A group	No. of localities of species from A group confirmed from 2000
<b>Forests</b>	16	10	6	624	71	33
Peatland	5	3	2	118	9	1
Meadows	5	4	1	329	10	3
<b>total</b>	<b>26</b>	<b>17</b>	<b>9</b>	<b>1071</b>	<b>90</b>	<b>37</b>

**Table 4.** Spearman rank correlation matrix between the area of forest, built-up area, protected area and values of indexes: floristic value (FV), floristic uniqueness (FU), numbers of species from A and B groups in the squares of the grid 10 x 10 km. The errors deleted in pairs, correlation indices for p<0.05.

	Built-up area [ha]	Protected area [ha]	FV	FU	No. of species from B group	No. of species from A group	Total no of species
Forest area [ha]	-0.46	0.29	0.31	0.24	0.27	0.30	0.31
Built-up area [ha]		-0.17	-0.07	-0.15	-0.04	-0.06	-0.06
Protected area [ha]			0.29	0.14	0.28	0.26	0.30
FV				0.74	0.95	0.56	0.99
FU					0.57	0.59	0.65
No. of species from B group						0.35	<b>0.98</b>
No. of species from A group							0.50

“twig epiphytes” populating clearcutting gaps in forests (Chase, 1978; Hagsater, Dumont and Pridgeon, 1996). In Central Poland, apart from the above-mentioned *Epipactis helleborine*, in the transformed habitats there have been reports of *Cephalanthera rubra*, *C. longifolia*, *Dactylorhiza majalis* and *Epipactis atrorubens* (authors own sightings). Nonetheless, the predominant number of orchids existing in this region has not been found in the above-mentioned sites.

Considering the valuation of Orchidaceae protection, the region of Central Poland is not uniform but is characterized by the existence of diversity centers. On the one hand, only in 28 out of the total number of 217 squares (10 x 10 km) have no orchid species been reported, which could indicate that the orchids with a considerable number of localities are distributed relatively uniformly in the region. On the

other hand, however, the spatial distribution of the FV and FU proves that the area under study is not at all uniform (Fig. 3). It is noteworthy that the distribution of the FV coincides much more with the distribution of species richness rather than FU. It means that it is the number of orchids reported in each square of the grid and not their rarity that contributes to the considerable floristic value index diversification, resulting from the fact that most species reported in Central Poland can be classified as rare. Even the taxa that were listed here as more frequent occur at a limited number of localities and only one species (*Dactylorhiza majalis*) has been confirmed in more than 50% of the primary 10 x 10 km grid squares.

The analysis of the distribution of areas with high floristic value and the distribution of protected areas indicates that, as a rule, in the squares with the

highest values there are protected areas. There is only one square (DE34) abundant in orchids, which is an exception to the rule. Altogether 12 species have been identified in the square including 4 of group A species which are rare in the region. However, only one of the four species has been confirmed and it is highly probable that most localities in that square are also historical. This territory is partly occupied by the open pit of the Bełchatów Coal Mine, which is the biggest in Poland with 44 km<sup>2</sup> of the combined surface area of the pit and a maximum depth of 190 m, and contributes to the dehydration of the territory (Żuk, 2012), eventually causing the disappearance of peatland and bogs.

Statistical analysis (Spearman's rank correlation) has not yielded any significant correlation between the area of the protected sites and the presence of orchids (Table 4). this is because the aforementioned sites frequently occupy a small fragment of the 10 km square. They also cover other environmentally significant areas without, however, any bearing on the presence of orchids. The analysis of specific localities in 2 x 2 km squares revealed the presence of protected areas for almost 80% of all contemporarily reported localities of group A species.

Spearman's rank correlation analysis has not indicated a pronounced link between the occurrence of orchids and the presence of forested areas in the grid squares, despite the fact that the majority of the orchids of Central Poland prefer forest habitats. This phenomenon is mostly a consequence of the high degree of transformation of forests in the region. In Central Poland fragments of forest similar to natural have been preserved but the predominant are relatively uniform managed pine forests.

Orchids representing different habitats, namely forest, peatland and meadow, have not been protected in Central Poland at the same level. Natural reserves are mostly forests. Out of 87 reserves in the region under study, only 6 protect non-forest vegetation (Kucharski, 2009). At the same time, most of open ecosystems protected under the NATURA 2000 program have been created between 2004-2009, so

they could not have played an important role in the protection of orchids, whose localities have been disappearing for decades. A positive example of active protection of meadow-peatland habitats is observed within the Natura 2000 site, Łąka w Bęczkowicach, which, since its foundation in 2002, through the implementation of agro-environmental schemes, has managed to preserve the population of *Liparis loeselii* and *Epipactis palustris* (Chmielewski et al., 2009, Zajęc, Kucharski and Kil, 2012).

The main cause for the disappearing orchid localities in Central Poland is the vanishing of their habitats. Only very few taxa have adapted to the contemporary man-made surrogate sites, such as managed forests, roadsides, quarries, ditches and rail embankments. From the analyses presented in this study it can be concluded that in order to implement effective protection of Orchidaceae in the European Lowlands it is necessary to design a specific strategy separately targeting each of the habitats. Actions aiming at establishing a complex conservation strategy of orchid habitats in Central Poland taking into account phenomena such as succession and maintenance of appropriate levels of ground water must be undertaken. The detection of regional key areas for the orchid's richness is important as well. Their preservation is especially significant from the scientific point of view as it enables studies of the biology and ecology of disappearing species and their capabilities of adapting to man-made habitats. Protection ex situ of the rarest discovered species should also be promoted.

## REFERENCES

- Adamowski, W. (1996). *Apofityzm wybranych gatunków storczykowatych (Orchidaceae) i jego uwarunkowania ekologiczne*. Białowieska Stacja Geobotaniczna Uniwersytetu Warszawskiego. Mscr. pracy doktorskiej, 1-96.
- Adamowski, W. (2006). Expansion of native orchids in anthropogenic habitats. *Pol. Bot. Stud.* **22**, 35-44.
- Arditti, J (1967). Factors affecting the germination of orchid seeds. *Bot. Rev.* **1(33)**, 1-97
- Atwood, J.T. (1986). The size of the Orchidaceae and the systematic distribution of epiphytic orchids. *Selbyana* **9**, 171-186.

- Batty, A.L., Brundrett, M.C., Dixon, K.W. and K. Sivasithamparam (2006). In situ symbiotic seed germination and propagation of terrestrial orchid seedlings for establishment at field sites. *Austral. J. Bot.* **54**, 375-381.
- Baumann, H., Kunkele, S. and R. Lorenz (2010). *Storczyki Europy i obszarów sąsiednich*. Multico, Warszawa, 1-327.
- Buttler, K.P. (2010). *Storczyki dziko rosnące gatunki i podgatunki Europy, Połnocnej Afryki i Bliskiego Wschodu*. Phototext, Warszawa, 1-286.
- Clemente, M. (2009). Orchid conservation and trade: are these concepts incompatible?. In: *Proceedings of the Second Scientific Conference on Andean Orchids*, (Eds. A.M. Pridgeon and J.P. Suarez), 46 -55. Universidad Técnica Particular de Loja, Loja, Ecuador.
- Chase, M.W., Cameron, K.M., Barrett, R.L. and J. V. Freudenstein (2003). DNA data and Orchidaceae systematics: a new phylogenetic classification. In: editors. *Orchid conservation. Natural History Publications*, (Eds. Dixon, K.W., Kell, S.P., Barrett, R.L. and P.J. Cribb), 69-89. Kota Kinabalu, Sabah.
- Chmielewski, B., Halladin-Dąbrowska, A., Niedźwiedzki, P. and N. Ratajczyk (2009). The outlook for protection of precious species and habitats at Natura 2000 site "Łąka w Bęczkowicach" *Przegląd Przyrodniczy XX, 3-4*, 79-86.
- Crib, P. and R. Govaerts (2005). Just how many orchids are there? *Proc. 18<sup>th</sup> World Orchid Conference*, 161-172.
- Cribb, P.J., Kell, S.P., Dixon, K.W. and R.L. Barrett (2003). *Orchid conservation: a global perspective*. Natural History Publications, Kota Kinabalu, Sabah, 1-24.
- Delforge, P. (2006). *Orchids of Europe, North Africa and the Middle East*. AC Black. Publishers, London, 1-640.
- Dickson, J.H. (1990). *Epipactis helleborine* in gardens and other urban habitats: an example for apophytism, In: *Urban ecology* (Eds. Sukopp H. and S. Hejny S.), 245-249. Academic Publishing, The Hague.
- Decree of the Minister of Environment of 5 January 2012 (Dz. U., poz. 81).
- Dressler, R.L. (1981). The orchids: natural history and classification. Cambridge, MA, USA: Harvard University Press. 1-332.
- Dressler, R.L. (1993). Phylogeny and Classification of the Orchid Family. Cambridge University Press, 1-314.
- Ellenberg, H (1986). *Vegetation Mitteleuropas mit den Alpen in Ökologischer Sicht*. Ed. 4, Eugen Ulmer, Stuttgart. 1-989.
- Ehlers, B.K., Olesen, J.M. and J.A. Gren (2002). Floral morphology and reproductive success in the orchid Epipactis helleborine: regional and local across-habitat variation. *Plant Syst. Evol.* **236** (1-2), 19-32.
- Gamarra, R., Ortúñez, E., Sanz, E., Esparza, E. and P. Galán (2010). Seeds in subtribe Orchidinae (Orchidaceae): the best morphological tool to support molecular analyses, In: *Tools for Identifying Biodiversity: Progress and Problems*, (Eds. P.L. Nimis and V.R. Lebbe), 323-326.
- Garay, L.A. and G. Sweet (1974). Orchidaceae. In: *Flora of the Lesser Antilles*, (Eds. R.A Howard). Harvard University, Jamaica Plains, Massachusetts, 1-178.
- Garcia, A (1992). Conserving the species-rich meadows of Europe. *Agr. Ecosyst. Environ.* **40**, 219-232.
- Gehu, J.M. (1979). Étude phytocoenotique analytique et globale de l'ensemble des vases et prés sales et saum, très de la façade atlantique française. Faculté de Farmacie, Univ. De Lille II et Station de Phytosociologie, Bailleul, 1-514.
- Gentry, A.H. and C.H. Dodson (1987). Diversity and biogeography of neotropical vascular epiphytes. *Ann. Missouri Bot. Gard.*, **74** (2), 205-233.
- Harrap, A. and S. Harrap (2010). *Orchids of Britain and Ireland*, A & C BLACK, London, 1-480.
- Jakubowska-Gabara, J., Witosławski, P. and K. Zielińska (2009). Flora naczyniowa – różnorodność, zmiany, zagrożenia. In: *Szata roślinna Polski środkowej*, (Eds. J.K. Kurowski), 57-80. Towarzystwo Ochrony Krajobrazu, Wydawnictwo EKO-GRAF, Łódź.
- Jakubowska-Gabara, J., Kucharski, L., Zielińska, K., Kołodziejek, J., Witosławski, P. and P. Popkiewicz (2011). *Atlas rozmieszczenia roślin naczyniowych w Polsce Środkowej. Gatunki chronione, rzadkie, ginące i zagrożone*. Wydawnictwo Uniwersytetu Łódzkiego, Łódź, 1-284.
- Jakubowska-Gabara, J., Kurzak, M., Kiedrzyński, M., Kopeć D., Kucharski, L., Kołodziejek J., Niedźwiecki P., Popkiewicz, P., Witosławski, P. and K. Zielińska (2012). New stations of rare, protected and threatened species of vascular plants in Central Poland. Part II. *Fragm. Florist. Geobot.* **19** (2), 349-359.
- Jalal, J.S. (2012). Status, threats and conservation strategies for orchids of western Himalaya, India. *J. Threatened Taxa.* **4** (15), 3401-3409.
- Kiedrzyński, M. and A. Stefaniak (2011). Występowanie rodzaju *Epipactis* Zinn 1757 w Puszczy Pilickiej na stanowiskach naturalnych i antropogenicznych, In: *Storczykowe w Polsce Biologia i Ochrona*, (Eds. Brzosko, E., Wróblewska A. and E. Jarmakowicz), 86-95. Białystok.
- Kondracki, J (2002). *Geografia regionalna Polski*. PWN, Warszawa, 1-440.
- Kucharski, L (1999). The plant cover of Central Poland and its changes in the 20<sup>th</sup> century. Wydawnictwo Uniwersytetu Łódzkiego, Łódź, 1-167.

- Kull T, Arditti J. and S.M. Wong (2009). *Orchid Biology: Reviews and Perspectives*, X Springer, 1-443.
- Kurowski, J.K. (2009). Szata roślinna Polski Środkowej. Towarzystwo Ochrony Krajobrazu w Łodzi. Wydawnictwo EKO-GRAF. Łódź, 1- 236.
- Kurowski, J.K. (2013). Obszary Natura 2000 w województwie łódzkim. RDOŚ Łódź, 1-184.
- Kurzweil, H (1993). Seed morphology in Southern African Orchidoideae. *P1. Syst. Evol.* **185**, 229-247.
- Light, M. and H. S. MacConaill (2006). Appearance and disappearance of a weedy orchid, *Epipactis helleborine*. *Folia Geobot.* **41**, 77-93.
- Lipiński, J (2006). *An outline of land amelioration development and its productive and environmental significance in view of studies*. *Acta Scient. Pol. Formatio Circumiectus.* **5** (1), 3-15.
- Matuszkiewicz, W (2001). *Przewodnik do oznaczania zbiorowisk roślinnych Polski*. Wydawnictwo Naukowe PWN, Warszawa, 1- 298.
- McCormick1, M.K., Whigham, D.F. and J. O'Neill (2004). Mycorrhizal diversity in photosynthetic terrestrial orchids. *New Phytol.* **163**, 425-438.
- Mirek, Z., Piękoś-Mirkowa, H., Zajac, A. and M. Zajac (2002). Flowering plants and pteridophytes of Poland. A checklist. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, 1-442.
- Olaczek, R (2012). Skarby przyrody i krajobrazu Polski. Multico, 1-768.
- Pillon, Y. and M. Chase (2007). Taxonomic Exaggeration and Its Effects on Orchid Conservation. *Conserv. Biol.* **21** (1), 263-265.
- Pridgeon, A (1996). Orchids: Status Survey and Conservation Action Plan. Paperback, 1-153.
- Rasmussen, H.N. and D.F. Whigham (2002). Phenology of roots and mycorrhiza in five orchid species differing in phototrophic strategy. *New Phytol.* **154**, 797-807.
- Scotland, R.W. and A.H. Wortley. (2003). How many species of seed plants are there? *Taxon.* **52**, 101-104.
- Shibu, S., Devi, B.C., Wesley, S. and P.S. Moin (2012). Ex situ conservation of endemic orchids of Western Ghats, Tamilnadu, India viaasymbiotic seed germination. *Adv. Appl. Sci. Res.* **3** (5), 3339-3343.
- Stefaniak, A., Karczewska, M. and A. Jakubska- Busse (2011). Wybrane cechy populacji *Epipactis helleborine* (L.) Crantz na terenie naturalnych Białowieskiego Parku Narodowego (BPN) oraz poddanych antropopresji w okolicach Puszczy Białowieskiej. In: *Storczykowe w Polsce Biologia i Ochrona*, (Eds. Brzosko E., Wróblewska A. and E. Jarmakowicz), 52-60. Białystok.
- Stefaniak, A. and M., Dąbrowska (2013). *Dactylorhiza sambucina* (L.) Soó (Orchidaceae) – a new position outside the contiguous range in Poland. *Arch. Biol. Sci., Belgrade.* **65** (2), 697-701.
- Swarts, N.D. and K.W. Dixon (2009). Terrestrial orchid conservation in the age of extinction. *Ann. Bot.* **104**, 543-556.
- Szlachetko, D (2010). Storczyki Europy i obszarów sąsiednich. Multico, Warszawa, 1-327.
- Szlachetko, D (1995). Systema Orchidalium, *Fragm. Florist. Geobot.*, 3, 1-152.
- Hagsater, E., Dumont, V. and A.M. Pridgeon (1996). Orchids: Status Survey and Conservation Action Plan IUNC, Gland, Switzerland and Cambrige UK, 1-154.
- Wittig, R. and M. Wittig (2007). *Epipactis helleborine* (L.) Crantz – the first (semi) ruderal orchid species of Central Europe. *Feddes Rep.* **118** (1-2), 46-50.
- Zajac, A (1978). Założenia metodyczne Atlasu rozmieszczenia roślin naczyniowych w Polsce. *Wiad. Bot.* **22** (3), 145-155.
- Zajac, I., Kucharski, L. and E. Kil (2012). Problems of protection of peatlands in Central Poland on the example SAC Natura 2000 “Łąka w Bęczkowicach” and adjacent areas. In: *Peatlands in semi-natural landscape – their transformation and the possibility of protection*. (Eds. J. Forysiak, Kucharski, L. and M. Ziulkiewicz), 11-18. Wydawnictwo Naukowe, Poznań.
- Zettler, L.W., Sharma, J. and F. Rasmussen (2004). Mycorrhizal diversity. In: *Orchid Conservation*, (Eds. Dixon, K., Cribb, P., Kell, S. and R. Barrett), 185-203. Malaysia.
- Zielinska, K., Zakubowska-Gabara, J. and J. Kołodziejek (2010). Adaptation of the “Herbarium” computer database to archiving and analysis of floristic data. *Acta Univ. Lodz., Folia Biol. Oecol.* **6**, 145–150.
- Żuk, S (2012). Największa w Polsce kopalnia węgla brunatnego. *Węgiel Brunatny* **1**, 78.