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Original Article

Cities and Disturbed Areas as Man-made Shelters for Orchid Communities

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Abstract

Many species from the family *Orchidaceae* spread in anthropogenic habitats and numerous studies documenting this process are known. Unfortunately, such data are scattered throughout various papers and reports, sometimes fragmentary and hard to reach (the 'grey literature'). Scientific elaboration on this topic still lacks a comprehensive review and summary of the scale of this phenomenon. Therefore, the main aim of this study was to gather, review and analyse such data, seeking the answer to the question whether the man-made habitats can be considered as refugee for orchids. The paper summarises data on the occurrence of orchid species in man-made habitats in Europe originating from published and unpublished sources. The particular emphasis was placed in urban habitats. For this purpose, the floristically data from 42 European cities were used. The conducted studies showed that the apohytism phenomenon in the family *Orchidaceae* was more widespread than had been previously reported. As a result, 70 species of orchids in the distinguished man-made habitats were found. The majority of the species grow on sand and clay pits. The most common species were *Epipactis helleborine* and *Dactylorhiza majalis*. The gathered data have confirmed that man-made habitats become refugee for many orchid species in the aftermath of the loss of their natural habitats. Thus, protection of sites transformed by man with orchid occurrence should be taken into consideration. These sites can become a source of very useful information for biogeographically and phylo-geographically analyses of many valuable and endangered species.

Keywords: anthropogenous habitats, apophytism, Orchidaceae, urban areas, species diversity

Introduction

Increasing anthropogenic impact on the environment and the related environmental transformation may result in the shrinking of areas of natural habitats or in the creation of substitute habitats novel in terms of ecological conditions (Jongman, 2002; Walker, 2007; Brun, 2009; Lundholm and Richardson 2010; Yamaura *et al.*, 2012). Plants often respond to the anthropogenic pressure by e.g.: a decline in the number of localities; the disappearance of entire populations; the breakdown of ecological connections, as well as changes of morphological and genetic diversity (Andrews, 1990; Hollingsworth and Dickson, 1997; Vitousek *et al.*, 1997; Reisch, 2006; Walker, 2007; Van Calster *et al.*, 2008; Niedrist *et al.*, 2009; Rewicz *et al.*, 2016; Zielińska *et al.*, 2016). However, a couple of indigenous species found suitable conditions in anthropogenic habitats (Formant *et al.*, 2009; Efimov, 2011; van Kleef *et al.*, 2012; Yamaura *et al.*, 2012). Those new habitats, often created by man, give many plant species a chance to survive. Moreover, the most flexible species may increase the number of localities and expand within, even outside the original geographical range.

It has been stated that anthropogenic habitats are colonised mainly by indigenous flora, characteristic of a given area (Piekarska-Stachowiak *et al.*, 2014). This process of spreading native species to human-made habitats is called *apophytism* (Jackowiak, 2006; Sukopp, 2006, 2008). In the rich literature concerning the influence of human disturbance on flora, there are many papers devoted to indigenous plant species spontaneously expanding in man-made habitats named *apophytes* (Kowarik, 1991; Jackowiak, 2006; Sukopp, 2006, 2008).

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Generally, man-made areas are settled by common species demonstrating wide tolerance to habitat conditions (Latzel *et al*., 2011; Piekarska-Stachowiak *et al*., 2014). However, disturbed habitats could also function as a refuge for rare and endangered plants (Greenwood and Gemmell, 1978; Heindl and Ullmann, 1991; Ullmann *et al*., 1998; Brändle *et al*., 2003; Nowak, 2005, 2006; Nowak and Nowak, 2006; Esfeld *et al*., 2008; Kirpluk and Bomanowska, 2008; Reisch, 2006; van Kleef *et al*., 2012; Zielińska *et al*., 2016). Surprisingly, orchids are often found in the apophytes group, but they are still one of the most threatened plant groups in the world (Sharrock and Jones, 2009; Bliz *et al*., 2011; The IUCN Red List of Threatened Species 2015). The disappearance of natural habitats of orchids is well documented. Industrialisation and the related urbanisation are transforming natural habitats with side effects such as air, soil and water pollution, which are responsible for reducing orchid populations (McCormick *et al*., 2004; Pfeifer and Jetschke, 2006; Sukopp, 2006; Rewicz *et al*., 2015). On the other hand, numerous studies have revealed that some orchid species were found in a great number of individuals in anthropogenous habitats that were either grossly modified by man or entirely man-made (Davis, 1979; Adamowski and Conti, 1991; Hollingsworth and Dickson, 1997; Adamowski, 2002, 2006; Heyde and Krug, 2000; Ehlers *et al*., 2002; Klimko *et al*., 2004; Light and MacConaill, 2005, 2006; Witting and Witting, 2007; Esfeld *et al*., 2008; Pedersen *et al*., 2013; Rewicz *et al*., 2016). Members of the family *Orchidaceae* can be found in varius types of anthropogenic habitats e.g.: roadsides, waste dumps, railway embankments, canal banks, poplar plantations, gravel pits, chalk and limestone quarries, lignite mining areas, etc. (e.g.: Davis, 1979; Adamowski, 2006; Esfeld *et al*., 2008). Such behaviour has been observed since the 19th century, when orchids were noticed on railway embankment and in sand limestone excavations in the United Kingdom for the first time (Prochazka and Velisek, 1983). According to Adamowski (2006), 53 orchid species occur in anthropogenically altered habitats, which is about 40% of the entire European flora of these plants. The most common taxa spread in secondary habitats in temperate Europe are species from the genus *Epipactis* and *Dactylorrhiza*. Those orchids have a shorter life cycle and broader ecological amplitudes in comparison to the other taxa (Adamowski, 2006).

Recently, in the scientific literature there are more and more reports indicating the appearance of orchids in urban areas (e.g.: Chronopoulos and Christodoulakis, 1996; Heinrich and Dietrich, 2008; Stefaniak *et al*., 2011; Barrico *et al*., 2012; Milović and Mitić, 2012; Tafra *et al*., 2012; Maslo, 2014; Stešević *et al*., 2014). This phenomenon needs special attention as towns and cities are a kind of conglomerates of transformed habitats which are not in the immediate vicinity of habitats natural for the analysed species.

Although the phenomenon of orchid species spreading onto transformed areas has been known for a long time and has been widely reported, there is a lack of research papers summarising the state of knowledge concerning this process. Therefore, the aim of the undertaken study was to complete the scattered data and to review the available information related to orchid species occurring in various man-made habitats, with a particular focus on urban habitats across Europe. In this paper, recent as well as historical data about orchids occurring in man-made habitats were reviewed to draw attention to this phenomenon and to provide a basis for future research. Besides the predominant review function of this paper, the final data set was used to address the question whether transformed areas can be important substitute sites for orchid species endangered in their natural landscape, and also to define the spectrum of anthropogenic habitats occupied by the species.

Materials and Methods

Data sources

The complete list of orchid species occurring in man-made habitats was prepared based on available literature data, including information published in scientific articles and data from the "grey literature", such as local monographs or technical reports. The paper included all types of anthropogenic habitats where orchids were found. The analyses covered only such species of orchids which had the *apophyte* status in the city i.e. native plants established in anthropogenic habitats (Jackowiak, 2006; Sukopp, 2006). We did not take into account species found in non-transformed areas which sometimes lie inside the urban areas, for example: protected areas or forest complexes located within administrative boundaries of cities. The distinguished anthropogenic habitats were grouped into eight categories: (A) forests influenced by industrial emissions; (B) industrial terrains; (C) industrial waste places; (D) greenery – parks, hedges, etc.; (E) plantations of ecologically alien trees; (F) plantations of non-native trees; (G) roadsides and embankments; (H) sand pits, clay pits and quarries.

For the analysis of occurrence of orchids in urban habitats, we selected available materials comprising complete lists of urban flora of 42 European cities, mainly from the area of Central and Northern Europe (Table 1).

Orchids occurring in urban habitats were grouped into frequency classes of the following categories (the number of occurrences of the species in all of the cities): I – up to 20%, II – 20-39%, III – 40-59%, IV – 60-79%, V – 80-100%.

Due to somewhat diversified extent of floristic studies carried out at various locations, data on species occurrence was encoded in a binary fashion (0-1, absent-present), without taking into account the degrees of quantitative occurrence.

Species nomenclature was adopted from Delforge (2006).

Data analysis

Spearman's rank correlation coefficients were used for the analysis of the correlation between the area of the examined cities and the number of orchid species and between the total numbers of vascular plants in particular cities and the number of orchids. The results were considered to be statistically significant for $p < 0.05$. The Detrended Correspondence Analysis (*DCA*) was used to assess variability within individual habitats in terms of occurrence of species from the *Orchidaceae* family. The software package STATISTICA PL. ver. 10 and Canoco ver.4.5 were used for all the above-mentioned numerical analyses (Statsoft Inc, 2013; Leps and Smilauer, 2003).

Results

Orchidaceae in anthropogenic habitats

As a result, 70 species of orchids in the investigated man-

Table 1. List of cities in which orchid species on man-made habitats were noted

No.	City	Country	GPScoordinates	Source of data
1.	Helsinki	Finland	60° 10'12.0" N 24° 56'18.4" E	Vähä-Piikkiö *et al*., 2004
2.	Sankt Petersburg	Russia	59° 56′ 0″ N, 30° 16′ 0″ E	Ignatieva and Konechnaya, 2004
3.	Jena	Germany	50° 56′ 0″ N, 11° 35′ 0″ E	Heinrich and Dietrich, 2008
4.	Wałbrzych	Poland	50° 46′ 15″ N, 16° 16′ 26″ E	Klimko *et al*., 2004
5.	Czeladź	Poland	50° 19′ 2″ N, 19° 4′ 13″ E	Tokarska-Guzik and Rostański, 1998
6.	Katowice	Poland	50° 15′ 51″ N, 19° 1′ 25″ E	Tokarska-Guzik and Rostański, 1997
7.	Jaworzno	Poland	50° 12′ 16″ N, 19° 16′ 12″ E	Tokarska-Guzik, 1997
8.	Szczytno	Poland	53° 33′ 46″ N, 20° 59′ 7″ E	Środa, 2002
9.	Warszawa	Poland	52° 13′ 56″ N, 21° 0′ 30″ E	Sudnik-Wójcikowska, 1987
10.	Poznań	Poland	52° 24′ 30″ N, 16° 56′ 3″ E	Jackowiak, 1993
11.	Łódź	Poland	51° 46′ 36″ N, 19° 27′ 17″ E	Witosławski, 2006
12.	Bielsk Podlaski	Poland	52° 46′ 6″ N, 23° 11′ 31″ E	Wołkowycki, 2003
13.	Koszalin	Poland	54° 11′ 25″ N, 16° 10′ 54″ E	Ćwikliński, 1971
14.	Słupsk	Poland	54° 27′ 57″ N, 17° 1′ 45″ E	Misiewicz, 1978
15.	Działoszyn	Poland	51° 7′ 4″ N, 18° 52′ 12″ E	Suwara-Szmigielska, 2010
16.	Warta	Poland	51° 42′ 29″ N, 18° 37′ 30″ E	Suwara-Szmigielska, 2010
17.	Głogówek	Poland	50° 20′ 38″ N, 17° 52′ 2″ E	Szotkowski, 1987
18.	Kraków	Poland	50° 3′ 41″ N, 19° 56′ 18″ E	Trzcińska-Tacik, 1979
19.	Uzhgorod	Ukraine	48° 37′ 26″ N, 22° 17′ 42″ E	Protopopova and Shevera, 2002
20.	Chernivtsi	Ukraine	48° 18′ 0″ N, 25° 56′ 0″ E	Korzhan, 2011
21.	Netishyn	Ukraine	50° 21′ 0″ N, 26° 38′ 0″ E	Gubar, 2006
22.	Kostopil	Ukraine	50° 53′ 0″ N, 26° 27′ 0″ E	Gutsmam, 2013
23.	Berezne	Ukraine	50° 59′ 48″ N, 26° 44′ 22″ E	Gutsmam, 2013
24.	Kamianets-Podilskyi	Ukraine	48° 41′ 0″ N, 26° 35′ 0″ E	Levanets͡ et al., 2004
25.	Kuznetsovsk	Ukraine	51° 20′ 40″ N, 25° 51′ 3″ E	Gutsmam, 2013
26.	Dubrovytsya	Ukraine	51° 34′ 0″ N, 26° 34′ 0″ E	Gutsmam, 2013
27.	Simferopol	Ukraine	44° 57′ 7″ N, 34° 6′ 8″ E	Iepikhin, 2008
28.	Shepetovka	Ukraine	50° 11′ 0″ N, 27° 4′ 0″ E	Gubar, 2006
29.	Vinnytsya	Ukraine	49° 14′ 0″ N, 28° 29′ 0″ E	Dobrovolska, unpub.
30.	Kharkiv	Ukraine	50° 0′ 16″ N, 36° 13′ 53″ E	Zvyagintseva, 2013
31.	Kirovohrad	Ukraine	48° 30′ 0″ N, 32° 16′ 0″ E	Arkushyna and Popova, 2010
32.	Chernihiv	Ukraine	51° 30′ 0″ N, 31° 18′ 0″ E	Zavyalova, 2010
33.	Pereyaslav-Khmelnytsky	Ukraine	50° 3′ 58″ N, 31° 26′ 32″ E	Kotsur *et al*., 2010
34.	Coimbra	Portugal	40° 15′ 0″ N, 8° 27′ 0″ E	Barrico *et al*., 2012
35.	Rome	Italy	41° 54′ 0″ N, 12° 30′ 0″ E	Celesti-Grapow *et al*., 2013
36.	Mostar	Bosnia and Herzegovina	43° 20′ 0″ N, 17° 48′ 0″ E	Maslo, 2014
37.	Zadar	Croatia	44° 6′ 51″ N, 15° 13′ 40″ E	Milović and Mitić, 2012
38.	Omiš	Croatia	43° 26′ 41″ N, 16° 41′ 19″ E	Tafra *et al*., 2012
39.	Podgorica	Montenegro	42° 26′ 2″ N, 19° 15′ 4″ E	Stešević *et al*., 2014
40.	Thessaloniki	Greece	40° 39′ 0″ N, 22° 54′ 0″ E	Krigas and Kokkini, 2005
41.	Patras	Greece	38° 15′ 0″ N, 21° 44′ 0″ E	Chronopoulos and Christodoulakis, 1996

made habitats were recorded (Table 2). The most common orchids occurring in the analysed anthropogenic sites were species from the genus *Epipactis* – *E. helleborine*, which occurred in all the types (8) of habitats, *E. atrorubens* recorded in six various habitats, and *E. palustris* observed in five (Fig. 1).

Numerous species were found in sand pits, clay pits, quarries (48), as well as on roadsides and embankments (35; Table 2). The most common species of orchids in these habitats were: *E. helleborine* (34) recorded 17 times on roadsides and embankments, *E. palustris* (18) recorded eight times in sand pits, clay pits and quarries, and *E. atrorubens* (18) recorded seven times on roadsides and embankments (Fig. 2).

The Detrended Correspondence Analysis (DCA) showed a group of species (*E. helleborine, L. ovata, D. majalis, D. fuschii, N. nidus-avis, P. bifolia and P. chlorantha*) most attached to six types of habitats. The first axis explains 28% of variability and the second axis 41% respectively (Fig. 3).

Orchidaceae in urban areas

In 42 analysed cities, 79 species of the *Orchidaceae* family, which belong to 25 genera, were found. The majority of the species (17) belong to the genus *Ophrys*, 12 to the genus *Dactylorhiza* and 8 to the genus *Epipactis* respectively.

The number of occurrences of orchids in the cities ranged from 1 up to 33. The largest numbers of species of orchids were reported in Rome (33), and also in Chernivtsi (23), Podgorica (20), and Warsaw (19). In ten cities, only one species of *Orchidaceae* was found (Table 3).

The analysis of the frequency classes of the particular taxa occurrences showed that the majority of the specimens belong to the first two classes of frequency: 54 species belong to the I class and 14 to the II class (Table 3). Only four species: *Epipactis helleborine*, *Dactylorhiza incarnata*, *Listera ovata* and *Platantera bifolia* belong to the most frequent classes (IV-V; Table 3).

The most common species in the examined cities were: *E. helleborine* – reported in 21 cities, *D. incarnata* (16), *L. ovata* (13), *P. bifolia* (14) and *D. majalis* (12; Table 3). As many as 27 species of orchids were found merely in one city, e.g.: *Orchis simia, O. provincialis, Ophrys sphegodes, O. mamosa, O. lutea, O.*

insectifera, *Himantoglossum hircinum* and *H. caprinum*.

The correlation between the area of the cities and the number of orchid species (r=0.1871) and between the number of all the species and the number of the orchid species in the city (r=-0.1571) was not very strong and statistically not significant in each case (Spearman's rank correlation, p<0.05).

Discussion

A quite high number of species detected in anthropogenic habitats, including urban ones, confirms that the phenomenon of apophytism is widespread among orchids. The most commonly quoted orchids which occur in man-made habitats

Table 2. Orchids species noted in distinguished man-made habitats

Species	Source
A - forests influenced by industrial emissions (N = 6 species)	
Goodyera repens (L.) R. Br.	Świercz, 2004, 2005, 2006, 2007
Epipactis atrorubens (Hoffm.) Besser	Świercz, 2004, 2005, 2006, 2007; Nissalo M, correspondence
Epipactis helleborine (L.) Crantz	Świercz, 2004, 2005, 2006, 2007
Malaxis monophyllos (L.) Sw.	Bernacki, 1987; Bróż and Maciejczak, 1991
Ophrys apifera Huds.	Nissalo M, correspondence
Platanthera bifolia (L.) Rich.	Świercz, 2004, 2005, 2006, 2007
B - industrial terrains (N = 4 species)	
Epipactis atrorubens (Hoffm.) Besser	Misiewicz, 1976
Epipactis helleborine (L.) Crantz	Misiewicz, 1976; Rebele, 1988
Epipactis palustris (L.) Crantz	Misiewicz, 1976
Listera ovata (L.) R. Br.	Rebele, 1988
C - industrial waste places (N = 12 species)	
Anacamptis pyramidalis (L.) Rich.	Sinker *et al*., 1991
Dactylorhiza incarnata (L.) Soó	Greenwood and Gemmel, 1978
Dactylorhiza praetermissa (*Druce*) *Soó*	Greenwood and Gemmel, 1978
Dactylorhiza purpurella (T. Stephenson and T.A. Stephenson) *Soó*	Greenwood and Gemmel, 1978
Epipactis atrorubens (Hoffm.) Besser	Jurkiewicz *et al*., 2001; Woch, 2012
Epipactis helleborine (L.) Crantz	Remmel, 1970; Klimko *et al*., 2004
Epipactis palustris (L.) Crantz	Greenwood and Gemmel, 1978; Rostański and Michalska, 2003; Błońska, 2010
Gymnadenia conopsea (L.) R.Br. subsp. *conopsea*	Greenwood and Gemmel, 1978
Ophrys apifera Huds.	Greenwood and Gemmel, 1978
Orchis mascula L.	Sarosiek J, correspondence
Orchis morio L.	Greenwood and Gemmel, 1978
Zeuxine strateumatica (Linnaeus) Schlechter	Siu and Chau, 1998
D - parks, hedges etc. greenery (N = 9 species)	
Dipodium roseum D.L. Jones and M.A. Clem.	Jolly, 1998
Epipactis helleborine (L.) Crantz	Sinker *et al*., 1991; Godefroid, 1995; Wittig and Wittig, 2007
Eulophia sinensis Miq.	Sun, 1997
Jacquiniella teretifolia (Sw.) Britton and P. Wilson	Solis-Montero *et al*., 2005
Maxillaria densa Lindl.	Solis-Montero *et al*., 2005
Scaphyglottis livida (*Lindl.*) *Schltr.*	Solis-Montero *et al*., 2005
Spiranthes hongkongensis S. Y. Hu et Barretto	Sun, 1997
Spiranthes spiralis (L.) Chevall.	Sinker *et al*., 1991
Zeuxine strateumatica (Linnaeus) Schlechter	Sun, 1997
E - plantations of ecologically alien trees (N = 8 species)	
Cephalanthera longifolia (L.) Fritsch	Burda, 1998; Berezutsky *et al*., 2014
Cephalanthera rubra (L.) Rich.	Conti, 1987; Berezutsky *et al*., 2014
Epipactis atrorubens (Hoffm.) Besser	Berezutsky *et al*., 2014
Epipactis helleborine (L.) Crantz	Berezutsky *et al*., 2014
Epipactis microphylla (Ehrh.) Sw.	Conti, 1987
Neottia nidus-avis (*L.*) L.C.M.Rich	Berezutsky *et al*., 2014
Ophrys apifera Huds.	Conti, 1987
Platanthera bifolia (L.) Rich.	Berezutsky *et al*., 2014
F - plantations of geographically alien trees (N = 13 species)	
Adenochilus gracilis Hook. f.	Abernethy, 1996
Cephalanthera longifolia (L.) Fritsch	Jakubska *et al*., 2006; Oklejewicz K, personal communication
Chiloglottis cornuta Hook.f.	Abernethy, 1996
Dactylorhiza fuchsii (Druce) Soó	Oklejewicz K, personal communication
Dactylorhiza majalis (Rchb.) P.F. Hunt et Summerh.	Oklejewicz K, personal communication
Dactylorhiza x braunii Halacsy	Oklejewicz K, personal communication
Epipactis helleborine (L.) Crantz	Geisselbrecht-Taferner and Mucina, 1995; Sauerl, 1995; Soczewka, 2000; Jakubska *et al*., 2006 ; Kirpluk I, personal communication
Epipactis palustris (L.) Crantz	Oklejewicz K, personal communications

Goodyera repens (L.) R. Br.	Adamowski W, unpubl.
Listera ovata (L.) R. Br.	Adamowski, 1996, 1998; Oklejewicz K, personal communication
Malaxis monophyllos (L.) Sw.	Oklejewicz K, personal communication
Platanthera bifolia (L.) Rich.	Adamowski, 1996, 1998; Oklejewicz K, personal communication
Platanthera chlorantha (Custer) Rchb.	Rutkowski L, personal communication
G - roadsides and embankments (N = 35 species)	
Cephalanthera damasonium (Mill.) Druce	Bernacki and Błońska, 2006
Cephalanthera rubra (L.) Rich.	Adamowski, 1996, 1998
Cypripedium acaule Aiton	Stuckey, 1967
Cypripedium calceolus L.	Case, 1987
Dactylorhiza fuchsii (Druce) Soó	Tabaka *et al*., 1988; Adamowski, 1996, 1998; Bernacki and Błońska, 2006
Dactylorhiza incarnata (L.) Soó	Tabaka *et al*., 1988
Dactylorhiza maculata (L.) Soó	Adamowski, 1996, 1998; Nissalo M, correspondence
Dactylorhiza majalis (Rchb.) P.F. Hunt et Summerh.	Hereźniak and Pierzgalski, 1991; Adamowski, 1996, 1998; Bernacki and Błońska, 2006
Dactylorhiza × *braunii* Halacsy	Adamowski, 1996, 1998
Diphylax griffithii (Hook.f.) Kraenzl.	Renz *et al*., 1984
Dipodium roseum D.L. Jones and M.A. Clem.	Jolly, 1998
Epipactis atrorubens (Hoffm.) Besser	Piotrowska, 1966; Nikolaeva and Zefirov, 1971; Wika, 1986; Šalak and Dvorak, 1989; Adamowski, 1996, 1998; Nowak, 1997; Bernacki and Błońska, 2006
Epipactis helleborine (L.) Crantz	Piotrowska, 1966; Ćwikliński, 1971; Nikolaeva and Zefirov, 1971; Renz, 1984; Jackowiak, 1986; Wika, 1986; Berdowski and Spałek, 1997; Sudnik-Wójcikowska, 1987; Szlachetko, 1988; Dickson, 1990; Stolarz, 1994; Adamowski, 1996, 1998; Nowak, 1997; Urbisz and Urbisz, 1998; Soczewka, 2000; Bernacki and Błońska, 2006; Dengubenko A.V., personal communication
Epipactis palustris (L.) Crantz	Hereźniak and Pierzgalski, 1991; Nowak, 1997; Wyrzykiewicz-Raszewska et al., 2001; Bernacki and Błońska, 2006; Nissalo M., correspondence
Epipactis × *schmalhausenii* K.Richter	Adamowski, 1996, 1998; Nowak, 1997
Eulophia sinensis Miq	Sun, 1997
Gymnadenia conopsea (L.) R. Brsubsp. *conopsea*	Bernacki and Błońska, 2006
Gymnadenia conopsea (L.) R. Br. subsp. *densiflora* (Wahlenb.) K. Richt.	Bernacki and Błońska, 2006
Herminium monorchis (L.) R.Br.	Renz, 1984
Liparis loeselii (L.) Rich.	Stuckey, 1967; Case, 1987
Listera ovata (L.) R. Br.	Kovalevskaja, 1971; Jehlík, 1986; Berdowski and Spałek, 1997; Nowak, 1997; Urbisz and Urbisz, 1998; Bernacki and Błońska, 2006
Malaxis monophyllos (L.) Sw.	Bernacki and Błońska, 2006
Neottia nidus-avis (*L.*) L.C.M.Rich	Adamowski, 1996, 1998; Nowak, 1997
Neottianthe cucullata (L.) Schltr.	Adamowski, 1996, 1998
Ophrys apifera Huds.	Wells and Cox, 1991
Ophrys insectifera L.	Bernacki and Błońska, 2006
Orchis militaris L.	Berezutsky *et al*., 2014
Platanthera bifolia (L.) Rich.	Berdowski and Spałek 1997; Adamowski 1996, 1998; Bernacki and Błońska 2006
Platanthera chlorantha (Custer) Rchb.	Adamowski, 1996, 1998
Spiranthes cernua (*L.*) *Rich.*	Stuckey, 1967
Spiranthes gracilis (Blume) Hassk.	Stuckey, 1967
Spiranthes hongkongensis S.Y.Hu and Barretto	Sun, 1997
Spiranthes lucida (H. H. Eaton) Ames	Case, 1987
Spiranthes spiralis (L.) Chevall.	Sinker *et al*., 1991
Spiranthes vernalis Engelm. and A.Gray	Stuckey, 1967
Zeuxine strateumatica (Linnaeus) Schlechter	Sun, 1997
H - sand pits, clay pits and quarries (N = 48 species)	
Anacamptis pyramidalis (L.) Rich.	Sinker *et al*., 1991; Heyde and Krug, 2000
Cephalanthera damasonium (Mill.) Druce	Koszela and Sarosiek, 1985; Heyde and Krug, 2000
Cephalanthera longifolia (L.) Fritsch	Koszela and Sarosiek, 1985
Cephalanthera rubra (L.) Rich.	Droz, 1994; Heyde and Krug, 2000
Coeloglossum viride (L.) Hartm.	Sinker *et al*., 1991
Corallorhiza trifida Châtel.	Heyde and Krug, 2000
Cypripedium calceolus L.	Case, 1987; Heyde and Krug, 2000
Dactylorhiza fuchsii (Druce) Soó	Sinker *et al*.1991; Heyde and Krug, 2000
Dactylorhiza incarnata (L.) Soó	Heyde and Krug, 2000
Dactylorhiza maculata (L.) Soó	Koszela and Sarosiek, 1985; Heyde and Krug, 2000; Czylok *et al*., 2008
Dactylorhiza majalis (Rchb.) P.F. Hunt et Summerh.	Heyde and Krug, 2000; Czylok *et al*., 2008

*Dactylorhiza praetermissa (*Druce*)* Soó	Sinker *et al*., 1991
Epipactis atrorubens (Hoffm.) Besser	Koszela and Sarosiek, 1985; Forman *et al*., 2003; Droz 1994; Heyde and Krug, 2000; Czylok *et al*. 2008;
Epipactis helleborine (L.) Crantz	Koszela and Sarosiek, 1985; Heyde and Krug, 2000; Czylok *et al*., 2008
Epipactis palustris (L.) Crantz	Droz, 1994; Mróz and Rudecki, 1995; Berdowski and Spałek, 1997; Chau and Siu, 1998; Heyde and Krug, 2000; Nowak and Witkowska, 2006; Czylok *et al*., 2008; Maciejewska-Rutkowska *et al*., 2008; Błońska, 2010
Gymnadenia conopsea (L.) R.Br.	Koszela and Sarosiek, 1985
Gymnadenia conopsea (L.) R. Br subsp. *conopsea*	Droz, 1994; Heyde and Krug, 2000
Habenaria linguella Lindl.	Chau and Siu, 1998
Liparis loeselii (L.) Rich.	Case, 1987; Heyde and Krug, 2000; Bzdon and Ciosek, 2006; Czylok *et al*., 2008; Błońska, 2010
Listera ovata (L.) R. Br.	Koszela and Sarosiek, 1985; Farrell, 1991; Heyde and Krug, 2000; Czylok *et al*., 2008
Malaxis monophyllos (L.) Sw.	Czylok *et al*., 2008
Neottia nidus-avis (*L.*) L.C.M.Rich	Sinker *et al*., 1991; Koszela and Sarosiek, 1985; Heyde and Krug, 2000
Ophrys apifera Huds.	Rossi, 1989; Sinker *et al*., 1991; Wells and Cox, 1991; Heyde and Krug, 2000
Ophrys bombyliflora Link	Rossi, 1989
Ophrys ciliata Link	Rossi, 1989
Ophrys garganica O.Danesch and E.Danesch	Rossi, 1989
Ophrys incubacea Bianca	Rossi, 1989
Ophrys sphegodes Mill.	Rossi, 1989
Ophrys tenthredinifera Willd.	Rossi, 1989
Ophrys × grampini Cortesi	Rossi, 1989
Ophrys × hoeppneri Rupper	Rossi, 1989
Ophrys × macchiatincubacea	Rossi, 1989
Orchis coriophora L.	Rossi, 1989
Orchis laxiflora (*Lam.*) R.M. Bateman, Pridgeon and M.W. Chase	Rossi, 1989
Orchis mascula L.	Koszela and Sarosiek, 1985
Orchis militaris L.	Farrell, 1991; Heyde and Krug, 2000
Orchis morio L.	Rossi, 1989
Orchis papilionacea L.	Rossi, 1989
Platanthera bifolia (L.) Rich.	Koszela and Sarosiek, 1985; Kukułczanka *et al*., 1985; Heyde and Krug, 2000
Platanthera chlorantha (Custer) Rchb.	Sinker *et al*., 1991; Heyde and Krug, 2000
Serapias lingua L.	Rossi, 1989
Serapias parviflora Parl.	Rossi, 1989
Serapias vomeracea (*Burm.f.*) *Briq.*	Rossi, 1989
Spiranthes lucida (H.H. Eaton) Ames	Case, 1987
Spiranthes sinensis (*Pers.*) *Ames*	Chau and Siu, 1998
Spiranthes spiralis (L.) Chevall.	Rossi, 1989
Zeuxine strateumatica (Linnaeus) Schlechter	Chau and Siu, 1998

include representatives of the genus *Epipactis* (mainly *E. helleborine*, *E. atrorubens, E. palustris*) and the genus *Dactylorhiza* (*D. majalis, D. fuschii* and *D. maculata*). Also, according to other authors, these orchids are the most frequently subjected to apophytisation (Dickson, 1990; Farrell, 1991; Ehlers *et al*., 2002; Bernacki and Błońska, 2006; Wittig and Wittig, 2007; Akhalkatsi *et al*., 2014). Among the aforementioned species, the most frequently reported in disturbed habitats was *E. helleborine*, which may be a result of its wide ecological amplitude, wide range of mycorrhizal spectrum with a fungal component, phenotypic plasticity and a considerable group of optional pollinators (Dickson, 1990; McCormick *et al*., 2004; Selosse *et al*., 2004; Rewicz *et al*., 2016).

The analysis of the available data has shown that populations of some species remain on anthropogenic habitats for several years, hence they can be called *euapophytes* (apophytes *sensu stricto*, i.e. permanently established in anthropogenic habitats) (Jackowiak, 2006). The same phenomenon was confirmed in the studies conducted by Adamowski and Conti (1991) and Adamowski (2006) on *Epipactis helleborine* and *Platanthera bifolia* growing in poplar plantations. Their observations show that populations of these orchids have remained in disturbed habitats for up to 25 years. Similar results were obtained by Light and MacConaill (2005, 2006) on *Epipactis helleborine*, and also by Stark (2010) on *Gymnadenia conopsea*, and Wyrzykiewicz-Raszewska *et al*. (2001) on *Epipactis palustris*.

Anthropogenic habitats not only become refugia for species considered to be rare or even endangered, but often have an impact on the phenotypic plasticity of their specimens, as well as demographics and the life story of entire populations. Quintana-Ascencio *et al*. (2007) has proven that populations of endemic species of *Hypericum cumulicola* from Florida growing in disturbed populations are characterised by shorter life length, faster growth and earlier production of seeds while compared to natural populations. Similar conclusions concerning phenotypic variation and maintaining the population of *Epipactis helleborine* on roadsides were drawn by Rewicz (2015, unpublished data) and Rewicz *et al*. (2016).

Table 3. Orchids species noted in analyzed cities

Species/Cities	Helsinki	St. Petersburg	Jena	Wałbrzych	Czeladź	Katowice	Jaworzno	Szczytno	Warszawa	Poznań	Łódź	Bielsk Podlaski	Koszalin	Słupsk	Działoszyn	Warta	Głogówek	Kraków	Uzhgorod	Chernivtsi	Netishyn	Kamianets-Podilskyi	Simferopol	Shepetovka	Vinnytsya	Kharkiv	Kirovohrad	Chernihiv	Pereyaslav-hmelnytsky	Ventspils	Coimbra	Rome	Mostar	Zadar	Omis	Podgorica	Tesaloniki	Patras	**TOTAL**	**FREQUENCY CLASS**
Aceras anthropophorum																																1							**1**	**I**
Anacamptis pyramidalis																															1	1		1			1	1	**5**	**II**
Barlia robertiana																																						1	**1**	**I**
Cephalanthera damasonium			1			1			1											1		1	1									1							**7**	**II**
C. longifolia						1														1		1										1	1	1					**6**	**II**
C. rubra							1			1										1			1										1						**5**	**II**
Corallorhiza trifida							1		1		1									1		1			1					1									**7**	**II**
Cypripedium calceolus		1	1																	1					1					1									**5**	**II**
Dactylorhiza cordigera																				1																			**1**	**I**
D. baltica																														1									**1**	**I**
D. fuchsii																												1	1	1									**3**	**I**
D. incarnata						1	1	1	1	1	1	1		1	1					1	1				1	1		1	1	1									**16**	**IV**
D. maculata		1				1			1	1				1						1	1					1				1									**9**	**III**
D. majalis			1			1	1		1	1	1					1				1					1		1		1										**11**	**III**
D. russowii																														1									**1**	**I**
D. sambucina									1																1								1						**3**	**I**
D. xaschersoniana							1				1																												**2**	**I**
D. xbraunii											1																												**1**	**I**
D. xmaculatifolia							1																																**1**	**I**
D. xvermeuleniana							1																																**1**	**I**
Epipactis atrorubens			1			1	1		1		1											1					1			1									**8**	**II**
E. helleborine	1	1	1	1	1		1		1	1	1		1				1		1	1	1	1		1	1	1		1		1			1						**21**	**V**
E. microphylla																																1							**1**	**I**
E. muelleri			1																													1							**2**	**I**
E. palustris						1	1		1	1								1		1	1				1	1			1	1									**11**	**III**
E. purpurata																				1		1																	**2**	**I**
E. xschmalhausenii						1	1																																**2**	**I**
E. xschulzei						1																																	**1**	**I**
Goodyera repens																														1									**1**	**I**
Gymnadenia conopsea	1						1		1											1					1				1	1									**7**	**II**
G. odoratissima																									1														**1**	**I**
Hammarbya paludosa	1																																						**1**	**I**
Herminium monorchis									1																														**1**	**I**
Himantoglossum adriaticum																																1							**1**	**I**
H. caprinum																																				1			**1**	**I**
H. hircinum			1																																				**1**	**I**
Limodorum abortivum																																1	1	1					**3**	**I**
Liparis loeselli									1	1											1									1									**4**	**I**
Listera cordata	1																													1									**2**	**I**
L. ovata	1	1	1			1	1		1	1	1						1			1					1				1	1		1							**14**	**IV**
Malaxis monophyllos	1	1				1	1																							1									**5**	**II**
Neotinea maculata																																1							**1**	**I**
Neotia nidus-avis	1								1	1	1								1	1		1			1				1	1									**10**	**III**
Ophrys apifera			1																													1	1		1	1			**5**	**II**
O. bertolonii																																1	1	1		1			**4**	**II**
O. bombyliflora																																1		1					**2**	**I**
O. exaltata																																1							**1**	**I**
O. fuciflora																																1	1	1					**3**	**I**
O. incubacea																																1				1			**2**	**I**
O. insectifera			1																																				**1**	**I**
O. lutea ssp. *murbeckii*																																		1				1	**2**	**I**
O. mammosa																																					1	1	**2**	**I**
O. scolopax																																	1	1		1			**3**	**I**

O. speculum																															1							1	I
O. sphegodes																															1	1	1	1	1			5	I
O. spruneri																																					1	1	I
O. tenthredinifera																															1				1			2	I
Orchis coriophora																				1					1	1		1	1			1		1		1		1	9	III
O. italica																																					1	1	I
O. laxiflora																													1			1				1		1	4	I
O. maculata																				1										1									2	I
O. militaris			1				1		1	1										1					1	1	1		1	1									10	III
O. morio						1	1		1	1									1	1					1				1			1	1			1			11	III
O. palustris																				1						1			1										3	I
O. papilionacea																																1		1		1			3	I
O. provincialis																																1	1			1			3	I
O. purpurea			1																	1			1			1						1	1	1					7	II
O. quadripunctata																																		1		1			2	I
O. simia																																1							1	I
O. tridentata																																1				1	1		3	I
O. ustulata									1	1															1														3	I
Platantera bifolia	1	1	1						1	1							1		1	1		1			1		1		1	1		1							14	IV
P. chlorantha		1	1							1										1		1			1														6	II
Serapias cordigera																																1							1	I
S. lingua																															1	1				1			3	I
S. parviflora																																1							1	I
S. vomeracea																																1		1		1		1	4	I
Spiranthes spiralis																																1	1	1		1	1		5	II
Traunsteinera globosa																									1														1	I
TOTAL	**8**	**7**	**14**	**1**	**1**	**12**	**16**	**1**	**18**	**14**	**9**	**1**	**1**	**2**	**1**	**1**	**3**	**1**	**4**	**23**	**5**	**9**	**3**	**1**	**18**	**8**	**4**	**4**	**13**	**20**	**2**	**33**	**14**	**15**	**2**	**17**	**4**	**9**	**319**	

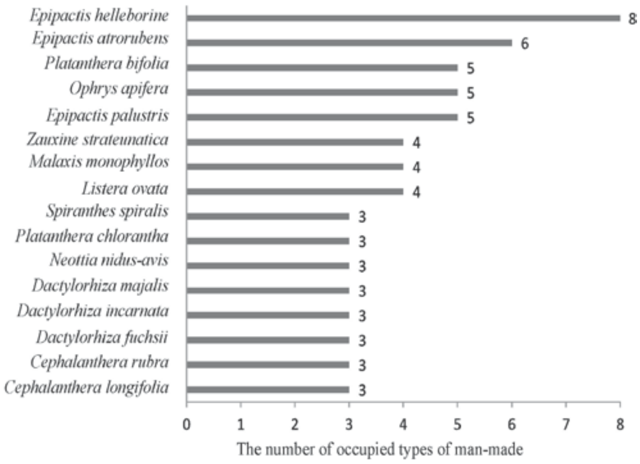

Fig. 1. The most common orchid species in various distinguished types of man-made habitats

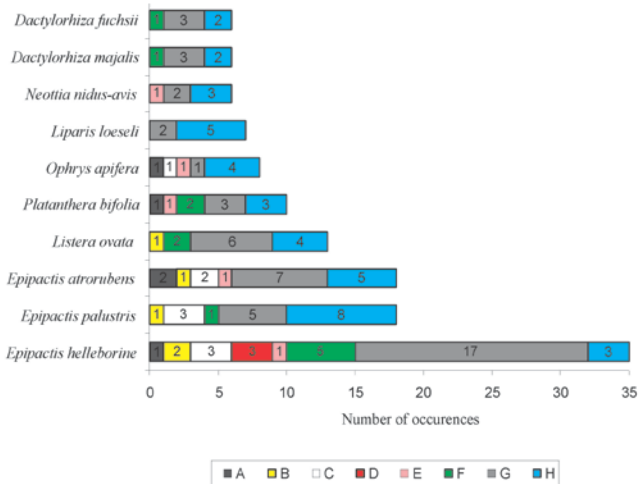

Fig. 2. The most frequently orchid species in the distinguished types of man-made habitats. (A) forests influenced by industrial emissions; (B) industrial terrains; (C) industrial waste places; (D) parks, hedges etc. greenery; (E) plantations of ecologically alien trees; (F) plantations of non-native trees; (G) roadsides and embankments; (H) sand pits, clay pits and quarries

Orchid species composition in anthropogenic habitats is a reflection of the species composition in the adjacent habitats, as well as of the geographical range of plants. Thus, it can explain the presence of the species from the genus *Dactylorhiza* and *Epipactis* in Eastern Europe, and the occurrence of the species from the genus *Serapias* and *Ophrys* in Western Europe. In the analysis of orchid occurrence in particular cities, it has also been observed that in Central European cities the species mentioned above dominate, while in the group of Balkan towns the species of the genus *Ophrys* and *Serapias* are dominant. This is due to the geographical ranges of the analysed taxa and the number of urban areas within the given part of Europe. In the case of the Balkans, the species of the *Ophrys* or *Serapias* genus are much more abundant, while in Central Europe and in the Ukraine those species do not occur (Delforge, 2006).

Such a great number of orchid species in various anthropogenic habitats poses the question as to whether man-made habitats are an "ecological equivalent" to naturally occurring habitats. It is pointed out that anthropogenic sites can be considered as temporary shelters, rather than mainstays, from which plants can expand further. Frequently, these refugia play the role of corridors for expansion of species and links between natural populations (Nowak and Nowak 2006; Esfeld *et al*., 2008; van Kleef *et al*., 2012).

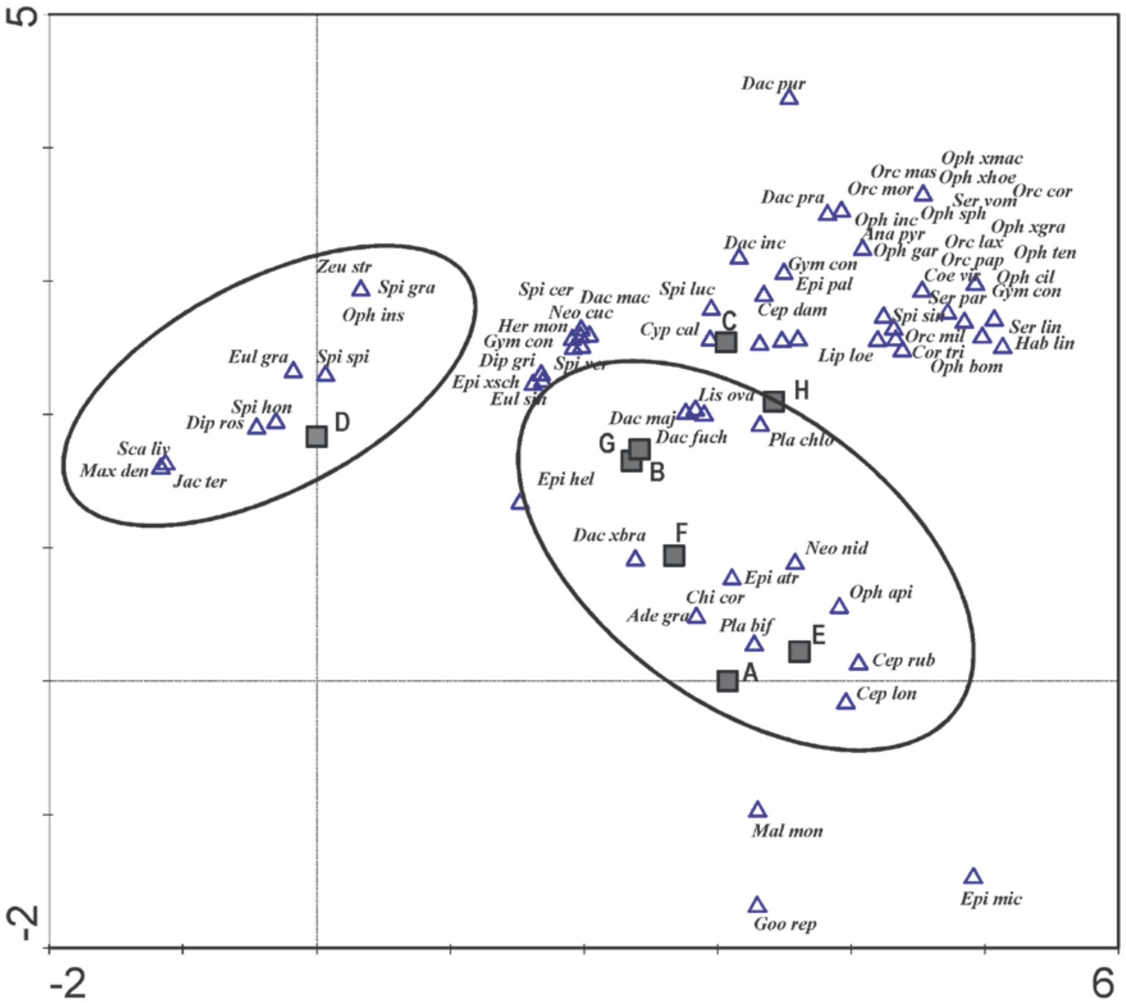

Fig. 3. Ordination diagram based on Detrended Correspondence Analysis (DCA) showing connection of orchid species to the different types of man-made habitats. A, B... H – distinguished types/kinds of man-made habitats, see Fig. 2

The prevalence of orchids and other valuable plants in anthropogenic habitats should draw attention to the problem of maintaining rare and endangered species in non-natural ecological systems (van Kleef *et al*., 2012; Zielińska *et al*., 2016). Although currently there is no literature data about species conservation carried out in populations of orchids in anthropogenic habitats, such populations should be observed in terms of their condition and stability.

Furthermore, occurrence of orchids in anthropogenic habitats provides an opportunity to use those populations in the educational process. Very often, those species are protected by law, hence it is possible to make some nature trails and organise outdoor lessons, enhancing nature conservation knowledge.

Conclusions

The conducted review has shown that some man-made and disturbed habitats host many rare orchids and could provide a chance for survival of those rare and valuable plant species. The need for the protection of sites of valuable orchid species in habitats strongly transformed by man should be taken into consideration at the present time.

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