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Russian Red Data Book Orchids: What Anthropogenic Factors are Leading to their Extinction in Regions?

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Abstract: The research of drivers leading to plant extinction is primary task in global biodiversity conservation. Despite Russia covers a large area, there is a lack of data on factors leading to plant extinction there, including orchids. We aimed to evaluate the anthropogenic drivers threaten orchids included in the Russian Red Data Books. For this purpose, we generalized and systematized data on orchids included in all relevant (i.e. published during recent 10–11 years) regional Red Data Books available online by 31 December 2020. For each Red Data Book orchid, we identified threats, i.e. drivers leading to species extinction, according to sections "Limiting factors" or "Limiting factors and threats" of regional Red Data Books. We found the total taxonomic list of Red Data Book orchids in the analyzed regions of Russia. The similarity of the lists of orchid taxa in analyzed regions has been established on the basis of Jaccard index. In regards of extinction drivers, we found what of them are most serious threats to orchids in the regions of Russian Federation. We believe that the conducting of the similar study for the whole amount of threatened plants of Russia will provide highly valuable results demanded all over the world.

Keywords: Orchidaceae; threat; extinction driver; plant conservation; Russia

1. Introduction

Extinction of species is the leading problems in biodiversity conservation at national and global levels. While an extinction of animals could be easier revealed (e.g. [1]), we need more time to prove a plant extinction event [2]. Humphreys et al. (2019) [3] stated that plant extinction studies should undoubtedly come with caveats, with indicating an underestimation of plant extinction rates, that could be explained by many unreported extinctions of poorly known taxa. Moreover, regional extinction events could be slower fixed at global assessments (e.g. Global IUCN Red List). Therefore, they play important role in estimation of plant extinctions able to be achieved at global scale through regional one.

Although Russia covers about 11.0% of total terrestrial area, there is a remarkable lack of biodiversity data from this country. This is well recordable in global reviews of biodiversity, including GBIF data [4], naturalized plants [5], *ex situ* plant conservation centers [6], peatland vegetation conservation [7]. We believe that it derives from low availability of biodiversity data written in Russian, being not prepared according to international publication standards. In particular, this concerns data on conservation and distribution of orchids. For instance, Khapugin (2020) [8] demonstrated that despite numerous studies of orchids in Protected Areas, there is a remarkable gap of data in Russia, even taking into account a high number of Protected Areas in this country.

Noteworthy, threats registered for each threatened plant could be recognized as extinction drivers. At the same time, various factors influence differently to a certain plant species extinction. In this study, we aimed to assess the threats indicated for orchid taxa included in the recently published Red Data Books of Russian regions. To achieve the goal, we evaluated i) taxonomic composition of Red Data Book orchid species in Russian regions, ii) main threats leading to the extinction of orchids in Russia. We assumed that extinction of orchids, as more attractive, vulnerable and wider known plants is more influenced by such factors as direct elimination of aboveground parts of plants (bouquet gathering) and disturbance of habitats.

2. Experiments

To study, we sampled the Red Data Books published and/or available online in 2010–2020. This period was selected to use the most modern and relevant data. As a result, we sampled and analysed data on Red Data Book orchid taxa from 51 regions (Figure 1).

Figure 1. Map of the Russian Federation, where the sampled regions are indicated. Empty regions refer to the absence of data on Red Data Book orchids (according to [9] with modifications).

To estimate drivers leading to the orchid taxa in Russia, we analyzed sections "Limiting factors" or "Limiting factors and threats" in each Red Data Book. We did not assess and judge on the completeness and reliability of original data for each orchid included in a Red Data Book. In addition, we did not estimate the validity or reasons of the inclusion of each orchid in Red Data Books of Russian regions. For establishing a scheme of extinction drivers, we applied mainly IUCN – CMP Unified Classification of Direct Threats [10], with modifications based on some relevant publications [9,11,12]. As a result, we used 12 extinction drivers, applied previously in [9], namely Agriculture, Fire, Forestry, Grazing, Habitat degradation, Habitat destruction, Hydrological disturbance, Invasion, Mining, Unknown, Urbanization, Utilization.

To standardize the scheme of scientific names, we used the database Plants of the World Online (http://www.plantsoftheworldonline.org/). For this purpose, we applied three-stage algorithm. At first stage, we ordered alphabetically all taxa. At second, scientific names of orchids were standardized according to POWO database. At third, we deleted duplicate taxa from species lists for further analysis.

The determination of the similarity of lists taxa from the regional Red Data Books using Jaccard similarity index. Jaccard's similarity index $JS = 100 \times C / (A + B - C)$ was calculated, where A = number of species in floristic list A; B = number of species in floristic list B; C = number of species shared between two (A and B) floristic lists. For this purpose we used function "vegdist" in package "vegan" [13] in software R ver. 3.4.0 [14].

3. Results and Discussion

3.1. Subsection

Originally, the accumulated sum of orchid taxa in 51 Red Data Books was 1070. After taxonomic standardization according to taxonomic systems, the total taxonomic list of Red Data Book plants in 51 Russian regions contained finally 120 taxa (Appendix A). The Red Data Book orchid species richness varied across the regions, ranging from 0 in the Astrakhan Region to 44 in Krasnodarsky Krai. This is partially in accordance with Efimov (2020) [15] who demonstrated the Krasnodarsky Krai as the region with the highest number of orchid taxa in Russia. The average number of Red Data Book species per region in Russia was 18 ± 8 (mean ± SD; median = 18). We also found no correlation between region's area and number of Red Data Book orchids per region ($r = 0.0.08$, $p < 0.95$). The most widespread species were *Cypripedium calceolus* L. (48 regions), and *Orchis militaris* L. (46 regions), followed by *Epipactis palustris* (L.) Crantz (42 regions), *Ponerorchis cucullata* (L.) X.H.Jin, Schuit. & W.T.Jin (40 regions), *Epipogium aphyllum* Sw. (39 regions), *Hammarbya paludosa* (L.) Kuntze (38 regions), Li*paris loeselii* (L.) Rich. (35 regions), *Corallorhiza trifida* Châtel. (33 regions) (Appendix A). Noteworthy, orchids were demonstrated to be the most widespread among all Red Data Book plant species in Russia (see [9]). This is in accordance with data on other studies demonstrated the high vulnerability of orchids in various regions around the world (e.g. [8,16,17]).

The 120 species belong to 39 genera. The highest number of taxa was found in *Dactylorhiza* (17 species), *Orchis* (11 species), *Platanthera* (11 species), Neottia (10 species). Other 32 genera were represented by one (e.g. *Calypso*, *Chamorchis*, *Gastrodia*, *Pogonia*) to seven (*Epipactis*) species (Appendix A).

We conducted the cluster analysis (Ward method; Figure 2) of the similarity of taxonomic lists of orchids in Russian regions, based on the Jaccard index similarity. The results reflected the biogeographical position of regions, with some deviations caused by the number of Red Data Book orchids per region. In the obtained dendrogram, four groups (A, B, C, D) are distinguishable. So, the large and complicated cluster A is represented by regions of the centre of European Russia and regions of Urals (e.g. Sverdlovsk Region, Chelyabinsk Region) and West Siberia (e.g. Tyumen Region, Omsk Region). Cluster B includes regions of East Siberia (e.g. Krasnoyarsk Region, Irkutsk Region) and north-west of European Russia (Novgorod Region and Pskov Region). Cluster C is certainly complicated, being represented by regions of the north of European Russia (Republic of Komi and Murmansk Region) and West Siberia (Khanty-Mansi Autonomous Okrug), as well as Russian Far East (e.g. Sakhalin Region) and East Siberia (e.g. Republic of Yakutia). Finally, cluster D includes predominantly regions of the south of European Russia (e.g. Krasnodarsky Krai, Voronezh Region). In this cluster, there is a highly different sub-cluster represented by Republic of Kalmykia, Yamalo-Nenetskiy Autonomous Okrug, and Kaliningrad Region, based on very low number of orchid species per region (i.e., one, four and six taxa, respectively). These results are similar to the data demonstrated in [9], highlighted that similarity of lists of Red Data Book plants reflects the geographical position of regions.

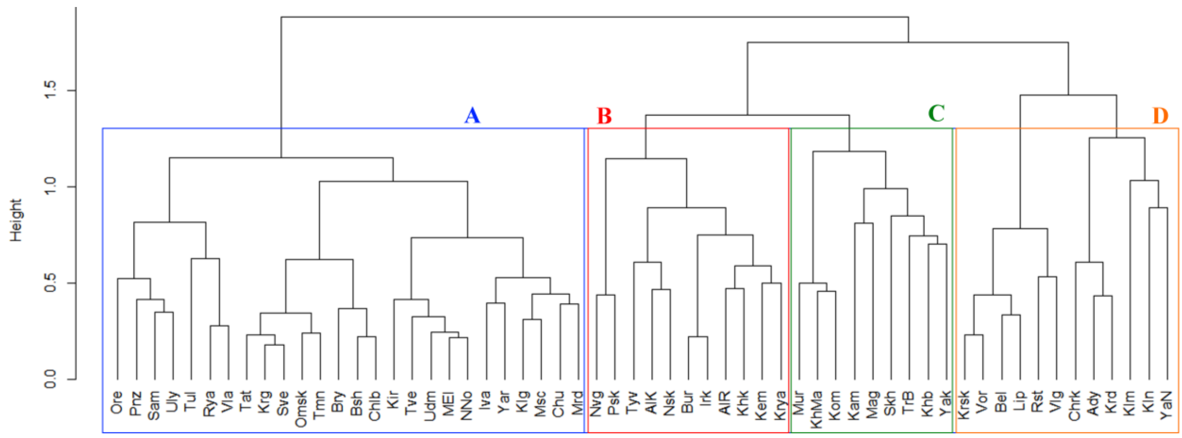

Figure 2. Cluster tree (Ward method, Euclidian distance) showing the similarity of regions based on the Jaccard index similarity of the lists of Red Data Book orchid species in Russian regions. Designations: Ady – Republic of Adygeya, AlK – Altaisky Krai, AlR – Republic of Altai, Bsh – Republic of Bashkiria, Bel – Belgorod Region, Bry – Bryansk Region, Bur – Republic of Buryatia, Chlb – Chelyabinsk Region, Chrk – Republic of Karachay-Cherkessia, Chu – Republic of Chuvashia, Irk – Irkutsk Region, Iva – Ivanovo Region, Kln – Kaliningrad Region, Klm – Republic of Kalmykia, Klg – Kaluga Region, Kam – Kamchatsky Krai, Kem – Kemerovo Region, Khb –Khabarovsky Krai, Khk – Republic of Khakassia, KhMa – Khanty-Mansi Autonomous Okrug, Kir – Kirov Region, Kom – Republic of Komi, Krd – Krasnodarsky Krai, Krya – Krasnoyarsky Krai, Krg – Kurgan Region, Krsk – Kursk Region, Lip – Lipetsk Region, Mag – Magadan Region, MEl – Republic of Mari El, Mrd – Republic of Mordovia, Msc – Moscow Region, Mur – Murmansk Region, NNo – Nizhniy Novgorod Region, Nvg – Novgorod Region, Nsk – Novosibirsk Region, Omsk – Omsk Region, Ore – Orenburg Region, Pnz – Penza Region, Psk – Pskov Region, Rst – Rostov Region, Rya – Ryazan Region, Skh – Sakhalin Region, Sam – Samara Region, Sve – Sverdlovsk Region, Tat – Republic of Tatarstan, TrB – Zabaikalsky Krai, Tul – Tula Region, Tve – Tver Region, Tmn – Tyumen Region, Tyv – Republic of Tyva, Udm – Republic of Udmurtia, Uly – Ulyanovsk Region, Vla – Vladimir Region, Vlg – Volgograd Region, Vor – Voronezh Region, Yak – Republic of Yakutia, YaN – Yamalo-Nenetskiy Autonomous Okrug, Yar – Yaroslavl Region.

3.2. Extinction drivers leading to the extinction of Red Data Book orchid species

Up to now, many studies demonstrated that habitat destruction and ecosystem overexploitation are major extinction drivers of plants and animals [18]. Based on our results, it was found that main drivers leading to extinction of orchids are generally the same that are known for all plants in various regions of the world [9,12,19]. Undoubtedly, various factors cause different influence on the possibility of orchid extinction. If we have these data, we may judge on measures counteracting to the disappearance of plants in certain regions. In our study, we revealed that among considered extinction drivers, habitat degradation (19.8%), hydrological disturbance (15.6%), urbanization (15.0%), and utilization (14.8%) play key roles in extinction of Red Data Book orchid species in Russia resulting from multiple drivers (Figure 3).

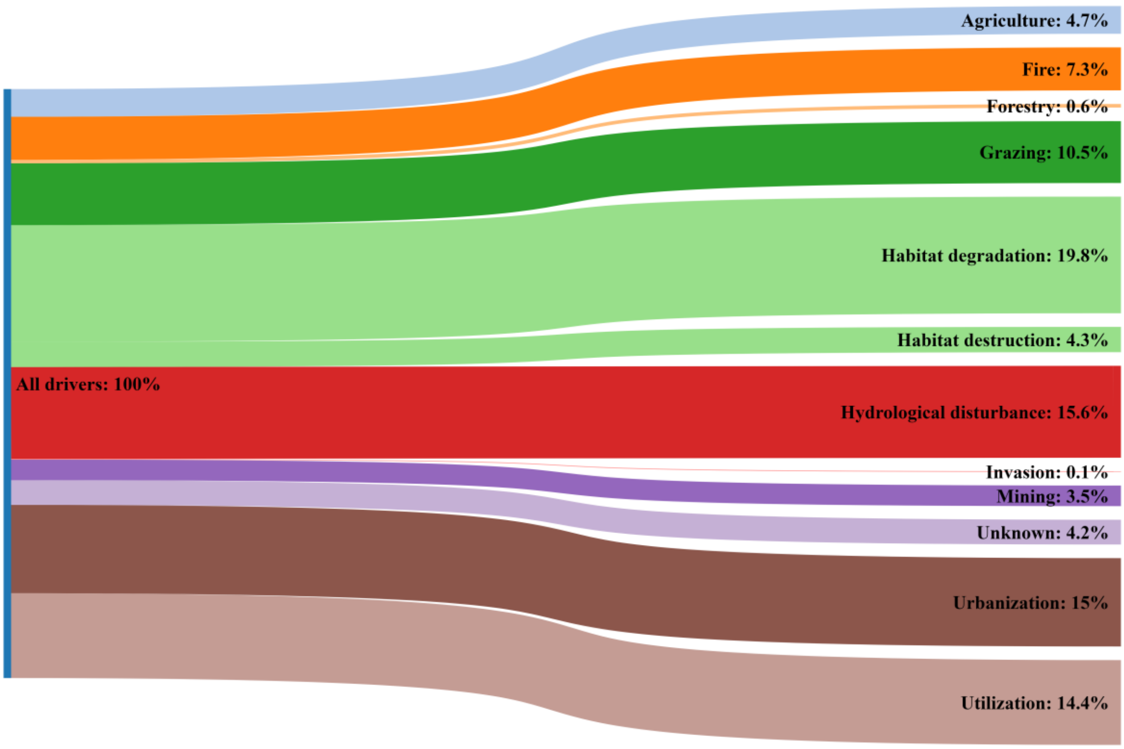

Figure 3. Primary drivers leading to orchid extinctions in Russia according to lists of Red Data Books of Russian regions.

Noteworthy, having data on plant extinction in Russia [9] and in worldwide [12], we may compare them with data on drivers causing orchid extinction in Russia. So, driver "Unknown" is a bit lower than for all Red Data Book plants in Russia (8.1%, see [9]) and even much lower than in global scale (48.3%, see [12]). This could be explained by high attractiveness and vulnerability of orchids around the world, that reflects the increased attention to these plants. In its turn, the high attractiveness is a reason, why drivers "Urbanization" and especially "Utilization" (including gathering for bouquets, and/or attempts to introduce orchids in backyards) (e.g. [20,21]).

The high proportion of the driver "Hydrological disturbance" is in accordance with data on sensitivity of orchids to this factor around the world. So, it was found the fruit set is influenced by precipitation amount [22,23]. The ground water level (e.g. [24]), as well as drought conditions (e.g. [25]) are also crucial for a number of orchid species.

The most impactful driver was "Habitat degradation", which also coincides with data on orchids in various regions of the world (e.g. [21,26–29]). Despite of the mentioned above, other drivers could influence considerably on various parameters of orchid populations, including "Grazing" (e.g. [28,30]), or "Fire" (e.g. 21,31]).

4. Conclusions

Our study of drivers leading to the orchid extinction of orchids contributes considerably the biodiversity conservation in Russia. Despite of a high number of Russian-language publications on orchid distribution and conservation, there was a lack in data on factors causing orchid extinction in the whole Russia. Our study could be considered as an attempt to estimate the drivers using internationally applied schemes (e.g. [9,12]) for orchids in Russia. Our results are considered as a basis for creation a national classification of threats to plants.

The data on threats to Red Data Book orchids in Russian regions could fill the gaps in the global knowledge on drivers leading to national extinction of orchid species. This is in accordance with data on extinction drivers in both Russian and global scale, where we found habitat degradation, hydrological disturbance, urbanization, and utilization to be leading factors threatening orchids in Russian regions. In compare to data on plant extinction in global and Russian scale, we found that orchids are more susceptible to direct elimination of aboveground parts of orchids (utilization and grazing), disturbance of habitats (urbanization, habitat degradation), and changes in water regime (hydrological disturbance). Expectedly, the geographical position of regions is associated with the species composition of orchid floras in these regions. On the basis of our results, we suggest conducting more detail studies of factors affecting or leading to species extinction of plants and particular plant groups (e.g. families, genera) in Russia or in wider area.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Taxonomic composition of Red Data Book orchids in the 51 studied regions of Russia.

Orchid species	Number of regions	Orchid genus	Number of species per genus
Cypripedium calceolus L.	48	*Dactylorhiza*	17
Orchis militaris L.	46	*Orchis*	11
Epipactis palustris (L.) Crantz	42	*Platanthera*	11
Ponerorchis cucullata (L.) X.H.Jin, Schuit. & W.T.Jin	40	*Neottia*	10
Epipogium aphyllum Sw.	39	*Epipactis*	7
Hammarbya paludosa (L.) Kuntze	38	*Cephalanthera*	6
Liparis loeselii (L.) Rich.	35	*Cypripedium*	6
Corallorhiza trifida Châtel.	33	*Anacamptis*	4
Cypripedium guttatum Sw.	30	*Liparis*	4
Gymnadenia conopsea (L.) R.Br.	30	*Ophrys*	4
Neottia ovata (L.) Bluff & Fingerh.	30	*Goodyera*	3
Malaxis monophyllos (L.) Sw.	27	*Gymnadenia*	3
Cypripedium macranthon Sw.	26	*Habenaria*	2
Epipactis atrorubens (Hoffm.) Besser	26	*Himantoglossum*	2
Neottia cordata (L.) Rich.	26	*Neotinea*	2
Dactylorhiza majalis subsp. *baltica* (Klinge) H.Sund.	26	*Ponerorchis*	2
Dactylorhiza viridis (L.) R.M.Bateman, Pridgeon & M.W.Chase	25	*Spiranthes*	2
Herminium monorchis (L.) R.Br.	25	*Traunsteinera*	2
Cephalanthera rubra (L.) Rich.	23	*Amitostigma*	1
Calypso bulbosa (L.) Oakes	22	*Calypso*	1
Neotinea ustulata (L.) R.M.Bateman, Pridgeon & M.W.Chase	22	*Chamorchis*	1
Neottia nidus-avis (L.) Rich.	22	*Corallorhiza*	1
Platanthera bifolia (L.) Rich.	22	*Cremastra*	1
Dactylorhiza incarnata (L.) Soó	20	*Dactylostalix*	1
Platanthera chlorantha (Custer) Rchb.	20	*Eleorchis*	1
Dactylorhiza maculata (L.) Soó	19	*Ephippianthus*	1
Dactylorhiza traunsteineri (Saut. ex Rchb.) Soó	18	*Epipogium*	1

Orchid species	Number of regions	Orchid genus	Number of species per genus
Epipactis helleborine (L.) Crantz	18	*Galearis*	1
Goodyera repens (L.) R.Br.	18	*Gastrodia*	1
Dactylorhiza fuchsii (Druce) Soó	17	*Hammarbya*	1
Dactylorhiza incarnata subsp. *cruenta* (O.F.Müll.) P.D.Sell	17	*Herminium*	1
Cypripedium × *ventricosum* Sw.	12	*Limodorum*	1
Dactylorhiza russowii (Klinge) Holub	12	*Malaxis*	1
Cephalanthera longifolia (L.) Fritsch	11	*Myrmechis*	1
Orchis mascula (L.) L.	10	*Neolindleya*	1
Spiranthes sinensis (Pers.) Ames	10	*Oreorchis*	1
Anacamptis coriophora (L.) R.M.Bateman, Pridgeon & M.W.Chase	9	*Pogonia*	1
Anacamptis palustris (Jacq.) R.M.Bateman, Pridgeon & M.W.Chase	7	*Pseudorchis*	1
Ophrys insectifera L.	7	*Serapias*	1
Platanthera fuscescens (L.) Kraenzl.	6	*Steveniella*	1
Platanthera obtusata subsp. *oligantha* (Turcz.) Hultén	5		
Cephalanthera damasonium (Mill.) Druce	4		
Dactylorhiza fuchsii subsp. *hebridensis* (Wilmott) Soó	4		
Neottia camtschatea (L.) Rchb.f.	4		
Anacamptis pyramidalis (L.) Rich.	3		
Dactylorhiza urvilleana (Steud.) H.Baumann & Künkele	3		
Gymnadenia odoratissima (L.) Rich.	3		
Limodorum abortivum (L.) Sw.	3		
Neolindleya camtschatica (Cham.) Nevski	3		
Neotinea tridentata (Scop.) R. M. Bateman, Pridgeon & M. W. Chase	3		
Orchis picta Raf.	3		
Pseudorchis albida (L.) Á.Löve & D.Löve	3		
Traunsteinera sphaerica (M.Bieb.) Schltr.	3		
Anacamptis morio (L.) R.M.Bateman, Pridgeon & M.W.Chase	2		
Cypripedium shanxiense S.C.Chen	2		
Cypripedium yatabeanum Makino	2		
Dactylorhiza incarnata subsp. *ochroleuca* (Wüstnei ex Boll) P.F.Hunt & Summerh.	2		
Dactylorhiza majalis (Rchb.) P.F.Hunt & Summerh.	2		
Dactylorhiza romana subsp. *georgica* (Klinge) Soó ex Renz & Taubenheim	2		
Dactylorhiza salina (Turcz. ex Lindl.) Soó	2		
Dactylorhiza traunsteineri subsp. *curvifolia* (F.Nyl.) Soó	2		
Eleorchis japonica (A.Gray) Maek.	2		
Ephippianthus sachalinensis Rchb.f.	2		
Gastrodia elata Blume	2		
Gymnadenia × *densiflora* (Wahlenb.) A.Dietr.	2		
Habenaria linearifolia Maxim.	2		

Orchid species	Number of regions	Orchid genus	Number of species per genus
Orchis pallens L.	2		
Orchis purpurea Huds.	2		
Orchis simia Lam.	2		
Orchis spitzelii Saut. ex W.D.J.Koch	2		
Oreorchis patens (Lindl.) Lindl.	2		
Platanthera chorisiana (Cham.) Rchb.f.	2		
Platanthera densa Freyn	2		
Platanthera ophrydioides F.Schmidt	2		
Platanthera tipuloides (L.f.) Lindl.	2		
Pogonia japonica Rchb.f.	2		
Ponerorchis chusua (D.Don) Soó	2		
Steveniella satyrioides (Spreng.) Schltr.	2		
Amitostigma kinoshitae (Makino) Schltr.	1		
Cephalanthera cucullata Boiss. & Heldr.	1		
Cephalanthera erecta (Thunb.) Blume	1		
Cephalanthera longibracteata Blume	1		
Chamorchis alpina (L.) Rich.	1		
Cremastra appendiculata var. *variabilis* (Blume) I.D.Lund	1		
Dactylorhiza fuchsii subsp. *psychrophila* (Schltr.) Holub	1		
Dactylorhiza sambucina (L.) Soó	1		
Dactylostalix ringens Rchb.f.	1		
Epipactis condensata Boiss. ex D.P.Young	1		
Epipactis microphylla (Ehrh.) Sw.	1		
Epipactis papillosa Franch. & Sav.	1		
Epipactis pontica Taubenheim	1		
Galearis cyclochila (Franch. & Sav.) Soó	1		
Goodyera henryi Rolfe	1		
Goodyera schlechtendaliana Rchb.f.	1		
Habenaria yezoensis H.Hara	1		
Himantoglossum caprinum (M.Bieb.) Spreng.	1		
Himantoglossum comperianum (Steven) P.Delforge	1		
Liparis kumokiri F.Maek.	1		
Liparis loeselii subsp. *sachalinensis* (Nakai) Efimov	1		
Liparis makinoana Schltr.	1		
Myrmechis japonica (Rchb.f.) Rolfe	1		
Neottia acuminata Schltr.	1		
Neottia convallarioides (Sw.) Rich.	1		
Neottia krasnojarica Antipova	1		
Neottia papilligera Schltr.	1		

Orchid species	Number of regions	Orchid genus	Number of species per genus
Neottia pinetorum (Lindl.) Szlach.	1		
Neottia puberula (Maxim.) Szlach.	1		
Ophrys apifera Huds.	1		
Ophrys caucasica Woronow ex Grossh.	1		
Ophrys sphegodes subsp. *mammosa* (Desf.) Soó ex E.Nelson	1		
Orchis × *colemanii* Cortesi	1		
Orchis × *wulffiana* Soó	1		
Orchis provincialis Balb. ex Lam. & DC.	1		
Orchis punctulata Steven ex Lindl.	1		
Platanthera bifolia subsp. *extremiorientalis* (Nevski) Soó	1		
Platanthera maximowicziana Schltr.	1		
Platanthera sachalinensis F.Schmidt	1		
Serapias vomeracea (Burm.f.) Briq.	1		
Spiranthes spiralis (L.) Chevall.	1		
Traunsteinera globosa (L.) Rchb.	1		

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