

Article

# Orchids of Mongolia: Taxonomy, Species Richness and Conservation Status

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**Abstract:** Orchidaceae is a diverse, globally important plant family with high conservation assessment and prioritization requirements. The checklist of Orchidaceae in Mongolia was updated based on herbarium materials, literature, and field observations. Mongolian orchids were revised as comprising 26 taxa belonging to 14 genera with major updates were conducted on *Herminium* and *Epipactis*. In particular, *H. alaschanicum*, previously noted in the Alashan Gobi region, was added to the flora of Mongolia based on literature and type specimens. *Epipactis helleborine* and *E. palustris* were excluded from the Mongolian flora owing to the absence of herbarium specimens and wild collection from Mongolia. Assessment of all orchid species at the national level resulted in 1, 4, 7, 11, and 2 species as critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), and data deficient (DD), respectively, according to IUCN criteria. Species richness and conservation gap analyses of 970 georeferenced orchid records based on 0.5° × 0.5° grid cells across 16 phytogeographical regions of Mongolia, showed that four phytogeographical regions, Khangai, Khuvgul, Khentii and Mongolian Dauria, have a high number of orchids. Regrettably, most orchid-rich locations in Mongolia are not fully within protected areas, highlighting the need for protection management updates. Based on herbarium collections, we prepared grid distribution maps of the 26 taxa using 40 × 40 km<sup>2</sup> grids. Photographs of 18 taxa taken during fieldwork were included, providing valuable information on species morphology and typical habitat.

**Keywords:** Orchidaceae; distribution pattern; flora of Mongolia; orchid-hotspot; protected area

## 1. Introduction

Orchidaceae is a diverse, globally important plant family with an urgent need for conservation assessment and prioritization [1–3]. The orchid family comprises approximately 30,300 species and is one of the largest and most widespread families of flowering plants worldwide [4,5]. Unfortunately, many orchid species are becoming extinct and

threatened owing to destruction of their habitats, use in traditional medicine, illegal trade, and climate change [3–6]. There are only ca. 600 orchid species listed as threatened on the global database of threatened species according to the International Union for the Conservation of Nature (IUCN) [6]. Additionally, Zizka et al. [2] provided an automated conservation assessment of the orchids including 13,910 species, of which 4,340 species are possibly threatened worldwide. Moreover, there are numerous publications on regional assessments of orchid species using IUCN categories and criteria [7–10]. For example, the lady's slipper orchid (*Cypripedium calceolus* L.) is classified of least concern on a global scale [11], whereas as endangered or vulnerable in many European and Asian countries on a national scale [8,9,11–14].

Several researchers have studied the species richness patterns of orchids in relation to the impact of climate change, and their conservation status on a regional or global scale [15–21]. For example, Huang et al. [15], revealed the hotspots and species richness of Orchidaceae in China, including 1,449 species, of which 97% were included in protected areas. In addition, Liu et al. [10] assessed 1,582 orchid taxa (of which 42.5% were threatened) for regional and global categories in China. Efimov [17] published a checklist of 135 orchid species in Russia, with a distribution pattern based on administrative regions. Moreover, Khapugin [22] summarized the global orchid distribution within protected areas based on published data, with the exception of Mongolia, owing to the lack of information. Hence, we aimed to fill this gap based on the revision of comprehensive herbariums and literature, as well as field observation data.

The species diversity of Orchidaceae in Mongolia is not particularly rich, with 27 taxa belonging to 15 genera reported [23–26]. Moreover, there are no endemic orchid species noted [27]; however, most of the species are considered as rare and threatened at the national level because of their restricted distribution, habitat disturbance (forest cutting, mining), and impact of climate change in Mongolia [9,26,28,29]. In general, orchids are distributed mainly in the northern, eastern, and central parts of Mongolia [23–26,30]. Northern Mongolia is the southern boundary of the Siberian boreal forest, and two large mountain systems, Khangai and Khentii stretch from the central part to the northeast of Mongolia, where the majority of forests and forest steppes are located [23]. Such forest habitats with an optimum edaphic environment facilitate orchid species' growth compared to the dry steppes and deserts in southern and south-eastern Mongolia. The first taxonomic key, growing habitats, and regional distribution of Orchidaceae in Mongolia was provided by Grubov [23], and comprised 21 species. Since 1982, most studies have focused on the national conservation status and regional distribution range [9,28,29]. More recently, some genera, such as *Herminium* L., *Spiranthes* Rich., and *Platanthera* Rich. have been revised based on morphological and molecular evidence from Asian countries, including Mongolia [31–33]. Our previous study reported *Cypripedium* Sw. with a photo illustration, its habitat, species examination, and a detailed distribution map of the country [26]. However, none of the above mentioned studies have employed quantitative approaches to assess species richness and to identify the conservation gap for orchids in Mongolia, owing to limited data collection and field observations. Hence, orchid revisions with an updated checklist, richness pattern, and detailed distribution map would be a valuable contribution to conservation management and its efforts in Mongolia.

The objectives of the present study were (i) to update the checklist and distribution map, (ii) to identify areas with high orchid species richness, and (iii) to assess all species in Mongolia using IUCN categories and criteria.

## 2. Materials and Methods

Data were obtained from three main sources: (i) herbarium collections from ALTB, GFW, HAL, K, LE, MW, NS, NSK, OSBU, TK, UBA and UBU (acronyms according to Thiers [34]), and the Virtual Guide to the Flora of Mongolia [35]; (ii) literature, and (iii) field survey observations between 2015 and 2020. In addition, several species observa-

tions were gathered from the iNaturalist platform under the “Flora of Mongolia” project (<https://www.inaturalist.org/projects/flora-of-mongolia?tab=observations>, accessed on 15 March 2021). Most of the orchid species were photographed during our field surveys, and herbarium specimens were deposited in the herbarium of the National University of Mongolia.

Taxonomic identification was based on Grubov [23,36], and recently published articles on genera *Herminium* [31], followed by *Spiranthes* [32], *Platanthera* [33], and *Dactylorhiza* [37]. The nomenclature of each taxon was followed based on the Plants of the World Online (<http://www.plantsoftheworldonline.org/>, accessed on 10 April 2021), International Plant Name Index ([www.ipni.org](http://www.ipni.org), accessed on 10 April 2021), and The Plant List ([www.theplantlist.org](http://www.theplantlist.org), accessed on 15 April 2021).

The assessments were based on IUCN criterion B (including sub-criteria B1; the extent of occurrence, EOO, and B2; the area of occupancy, AOO) which uses geographic range size and evidence of declining or fragmented populations [38]. Criterion B is suitable for estimating conservation status even when data are limited and the distribution of a taxon is only known from a few georeferenced records [38]. The EOO and AOO were estimated using the package ConR [39] in R 4.0.3. [40]. The minimum AOO was estimated based on a user-defined grid cell of 2 km<sup>2</sup>, as recommended by the IUCN [38].

We created a grid net for Mongolia with a spatial resolution of 0.5° × 0.5° grid size (approximately 50 × 50 km<sup>2</sup>) using the Fishnet tool in ArcGIS 10.3 [41]. The country was divided into 715 grid cells. The species richness map was constructed by calculating the total number of species within each cell based on the grid net and species distribution data. The same approach was applied to create a species richness map of the 16 phytogeographical regions defined by Grubov [23]. Additionally, we used geographic information system data of protected areas (downloaded from the World Database on Protected Area (WDPA), <https://protectedplanet.net/>, accessed on 20 March 2021) to determine the extent to which species were included in the protected areas. We excluded nature monuments, which are a category of protected areas in Mongolia, as they usually cover small areas and are primarily dedicated to the preservation of historical and cultural heritage.

The point distribution map of each taxon was based on a 40 × 40 km<sup>2</sup> grid cell size in Mongolia. The distribution points, marked by three different symbols, are summarized in Table 1.

**Table 1.** Mapping symbols used in the distribution maps.

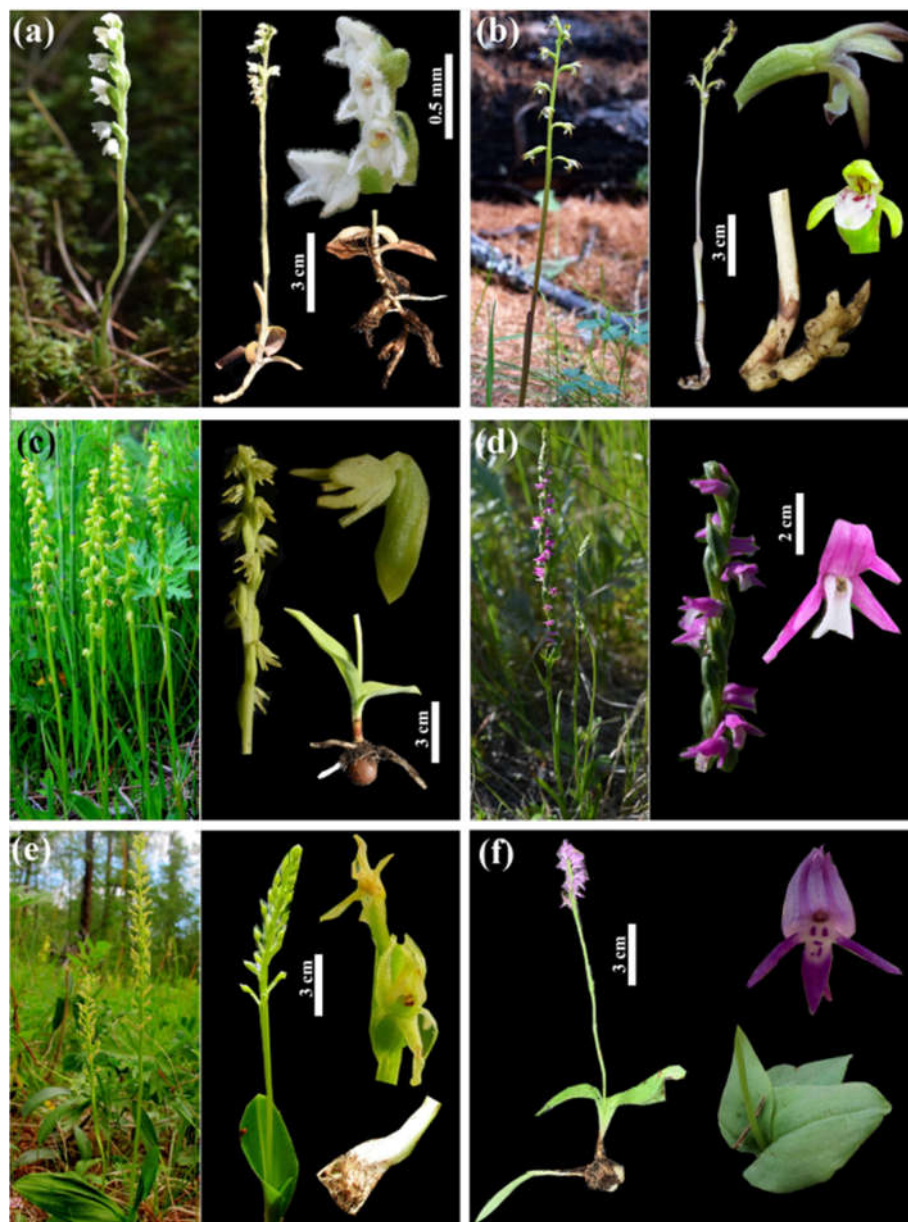
Symbols	Description	Brief Explanation
●	Before 2000	All dots indicate herbarium collections
○	After 2000	
▲	All other	Based on other sources: literature and observations from iNaturalist

### 3. Results

#### 3.1. Checklist and Threatened Status

The updated checklist of Orchidaceae is represented by 26 taxa (including 24 species, 1 subspecies, and 1 nothospecies) from 14 genera in Mongolia (Table 2). Among them, *Dactylorhiza* (six taxa), *Cypripedium* (four taxa) and *Platanthera* (three taxa) were the most species-rich genera in Mongolia. All species were assessed for their regional conservation status: one species (*Calypso bulbosa*) was evaluated as critically endangered, four species (*Dactylorhiza fuchsii*, *Orchis militaris*, *Neottia camtschatea* and *N. puberula*) as endangered, and seven species as vulnerable. The remaining 13 taxa (11 and two) were classified as near threatened and data deficient, respectively (Table 2). Only *Cypripedium* × *ventricosum* was not assessed in this study because of its hybrid nature. Photographs with detailed parts of the representatives of 18 taxa are shown in Figures 1–3.

We prepared the grid distribution maps of the 26 taxa, which are available in Appendix A. Based on these results, several species, namely *Goodyera repens* (Figures 1a and A14), *Gymnadenia conopsea* (Figures 3a and A15), *Corallorhiza trifida* (Figures 1b and A2), *Herminium monorchis* (Figures 1c and A17), *Dactylorhiza viridis*, (Figures 3c and A12), *D. salina* (Figures 3d and A10), *Cypripedium guttatum* (Figure 2b and A4), and *Spiranthes australis* (Figures 1d and A26) were observed to be widely distributed in the northern and central parts of Mongolia. Some species such as *Calypso bulbosa* (Figure A1), *Herminium alaschanicum* (Figures 3h and A16) and *Orchis militaris* (Figures 3g and A21) occurred only in a few locations in northern, central, and southern Mongolia (Appendix A). Finally, Table 2 summarizes the number of collection records, distribution size of EOO and AOO, conservation status, regional distribution range, and preserved herbaria.



**Figure 1.** Representative taxa of Orchidaceae in Mongolia: (a) *Goodyera repens*, (b) *Corallorhiza trifida*, (c) *Herminium monorchis*, (d) *Spiranthes australis*, (e) *Malaxis monophyllos*, (f) *Ponerorchis cucullata*. (Photos: (a–c) by Sh. Baasanmunkh; (c–f) by H.J. Choi, T. Namuulin).

**Table 2.** The checklist of Orchidaceae in Mongolia with red list assessments, regional distribution, and preserved herbaria.

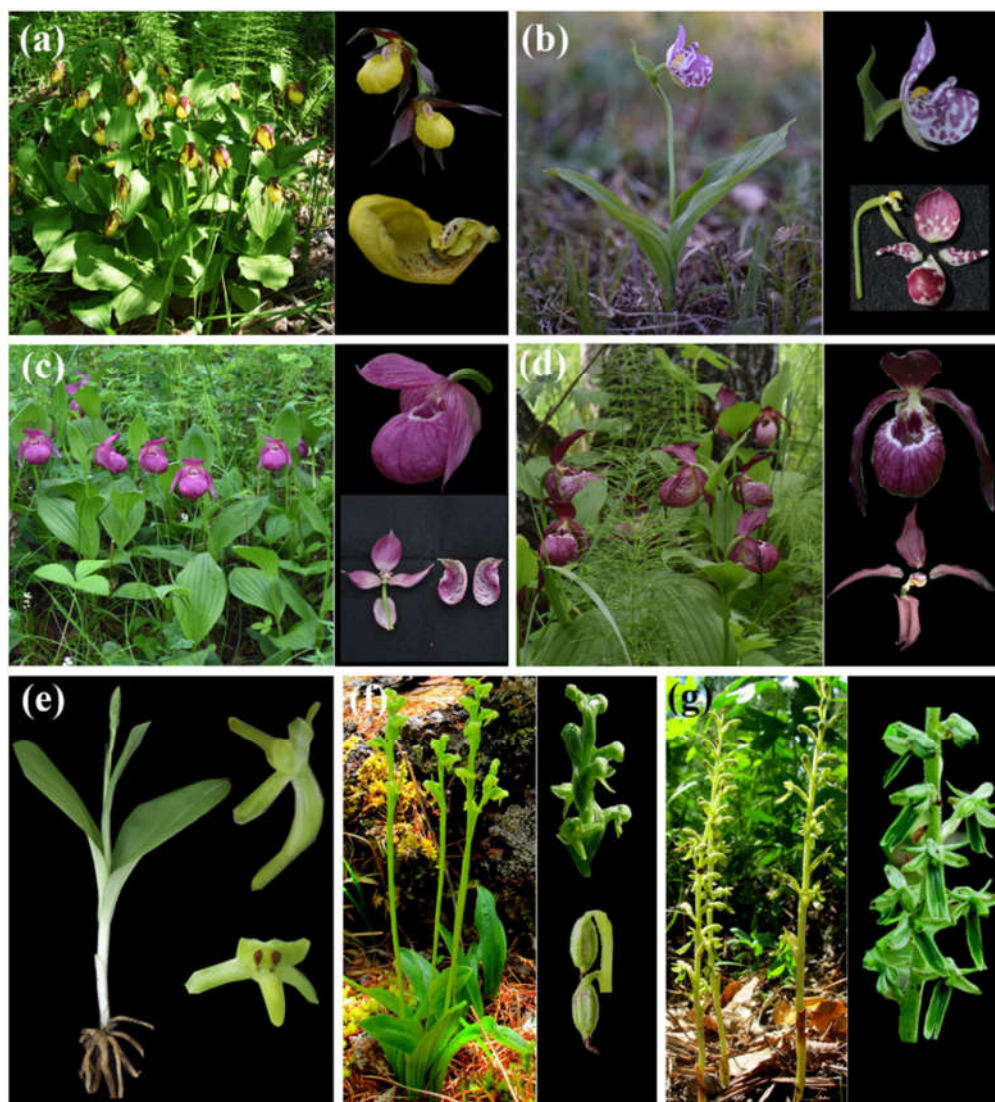
No.	Accepted Taxon Name	Number of Records	EOO km <sup>2</sup>	AOO km <sup>2</sup>	Threat Category and Criteria in This Study	Pervious Threat Category and Criteria with Reference	Phytogeographical Regions in This Study	Preserved Herbaria
1	<i>Calypso bulbosa</i> (L.) Oakes	2	–	8	CR B2a	CR B1+B2a,b(iii) [28]	2, 4	LE, MW
2	<i>Corallorhiza trifida</i> Châtel.	37	301,097	140	NT	VU D2 [28]	1, 2, 4	GFW, HAL, LE, MW, UBA, UBU
3	<i>Cypripedium calceolus</i> L.	37	69,920	128	NT	VU B2ab(ii,iii) [28]	1, 2, 4	LE, MW, UBA, UBU
4	<i>Cypripedium guttatum</i> Sw.	106	522,094	404	NT	VU A4c [28]	1, 2, 3, 4, 5	GFW, HAL, KHU, LE, MW, UBA, UBU
5	<i>Cypripedium macranthos</i> Sw.	40	157,732	144	VU B1a	EN B2ab(ii,iii,iv) [29]	1, 2, 4, 5	LE, MW, NS, UBA, UBU
6	<i>Cypripedium × ventricosum</i> Sw.	3	15,146	12	NA	CR B1b(i,ii,iii,iv) [9]	2	MW, UBU
7	<i>Dactylorhiza fuchsii</i> (Druce.) Soó	12	12,247	36	EN B2a	CR B1ab(iii,iv)+2ab(iii,iv) [29]	2, 4	LE, UBA, UBU
8	<i>Dactylorhiza incarnata</i> (L.) Soó	12	128,431	32	VU B1a+B2a	VU B2ab(ii,iii,iv) [29]	3, 5	LE, MW, UBU
9	<i>Dactylorhiza incarnata</i> subsp. <i>cruenta</i> (O.F.Mull.) P.D.Sell	1	–	–	DD	–	3	MW
10	<i>Dactylorhiza salina</i> (Turcz. ex Lindl.) Soó	159	1,170,647	616	NT	–	1–11, 14	GFW, HAL, KHU, LE, NS, NSK, UBA, UBU
11	<i>Dactylorhiza umbrosa</i> (Kar. & Kir.) Nevski	14	351,909	56	NT	–	1, 3, 4, 7, 10, 14	LE, MW
12	<i>Dactylorhiza viridis</i> (L.) R.M.Bateman, Pridgeon & M.W.Chase	82	589,844	316	NT	–	1–7	LE, MW, NS, UBA, UBU
13	<i>Epipogium aphyllum</i> Sw.	14	125,481	56	VU B1a	VU B2ab(i,ii,iii) [28]	1, 2, 3, 4	LE, MW, UBA
14	<i>Goodyera repens</i> (L.) R.Br.	58	426,394	220	NT	–	1, 2, 3, 4, 6	GFW, HAL, LE, MW, OSBU, UBA, UBU
15	<i>Gymnadenia conopsea</i> (L.) R.Br.	126	551,578	496	NT	VU B1ab(ii,iii)+B2ab(ii,iii) [29]	1, 2, 3, 4, 5	GFW, HAL, LE, MW, UBA, UBU
16	<i>Herminium alaschanicum</i> Maxim.	1	–	–	DD	–	16	K, LE
17	<i>Herminium monorchis</i> (L.) R.Br.	62	551,976	240	NT	NT [9]	1–5, 8, 9, 10	GFW, HAL, LE, MW, UBA, UBU
18	<i>Malaxis monophyllos</i> (L.) Sw.	60	673,163	236	NT	–	1, 2, 3, 4, 5	GFW, HAL, LE, MW, UBA, UBU
19	<i>Neottia camtschatea</i> (L.) Rchb.f.	3	25,822	12	EN B2a	CR D1 [29]	1, 2, 3, 7	GFW, HAL, MW
20	<i>Neottia puberula</i> (Maxim.) Szlach.	3	12	12	EN B1a+B2a	–	5	MW
21	<i>Orchis militaris</i> L.	11	2,210	16	EN B1a+B2a	EN B2ab(i,iii,iv) [29]	3, 4	HAL, LE, MW
22	<i>Platanthera bifolia</i> (L.) Rich.	11	60,111	44	VU B1a	CR D1 [29]	1, 2, 3, 4	LE, UBA
23	<i>Platanthera fuscescens</i> (L.) Kraenzl.	14	119,109	56	VU B1a	–	2, 3, 4, 5	LE, MW, UBA

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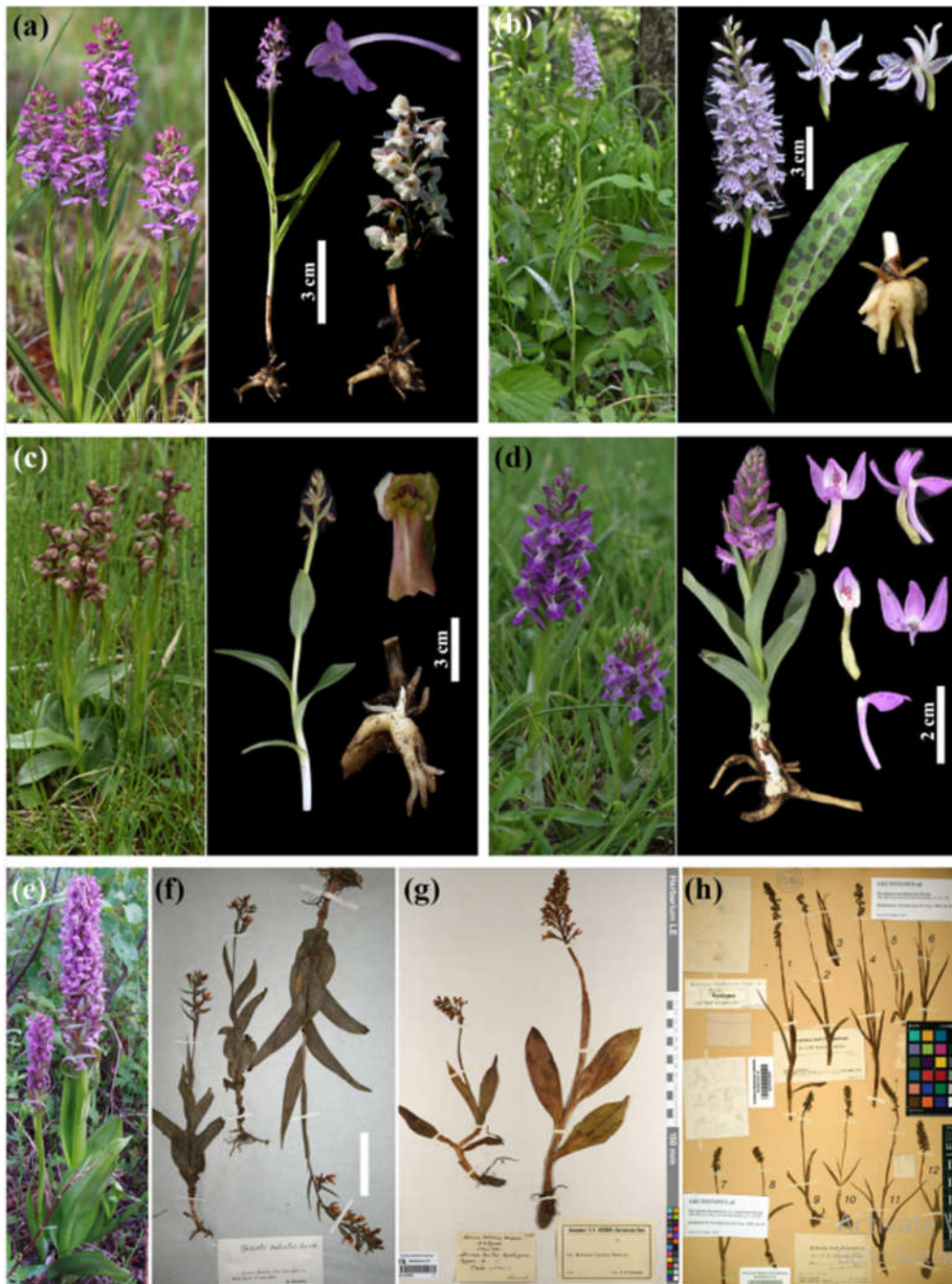
24	<i>Platanthera oligantha</i> Turcz.	11	30,189	44	VU B1a	–	1, 3	LE, MW
25	<i>Ponerorchis cucullata</i> (L.) X.H.Jin, Schuit. and W.T.Jin	33	237,000	128	VU B1a	CR D1 [29]	1, 2, 3, 4	HAL, LE, MW, UBA, UBU
26	<i>Spiranthes australis</i> (R.Br.) Lindl.	53	623,337	208	NT	–	2, 3, 4, 5, 8, 9, 10	LE, MW, NS, UBA, UBU

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EOO, extent of occurrence; AOO, area of occupancy; CR, critically endangered; EN, endangered; VU, vulnerable; NT, near threatened; DD, data deficient; NA, not assessed.



**Figure 2.** Representative taxa of Orchidaceae in Mongolia: (a) *Cypripedium calceolus*, (b) *Cypripedium guttatum*, (c) *Cypripedium macranthos*, (d) *Cypripedium* × *ventricosum*, (e) *Platanthera fuscescens*, (f) *Platanthera oligantha*, (g) *Neottia camtschatea* (Photos: (a–d) by Sh. Baasanmunkh, (e) by B. Oyuntsetseg and (f,g) by B. Josef).



**Figure 3.** Representative taxa of Orchidaceae in Mongolia: (a) *Gymnadenia conopsea*, (b) *Dactylorhiza fuchsii*, (c) *D. viridis*, (d) *D. umbrosa*, (e) *D. salina*, (f) *Epipactis palustris*, (g) *Orchis militaris*, (h) *Herminium alaschanicum* (1–6, 11) and *H. alaschanicum* var. *tanguticum* (7–10, 12) (Photos: (a–d) by Sh. Baasanmunkh, (e) by Ch. Dulamsuren, (f) from T.K. and (g,h) from L.E.).

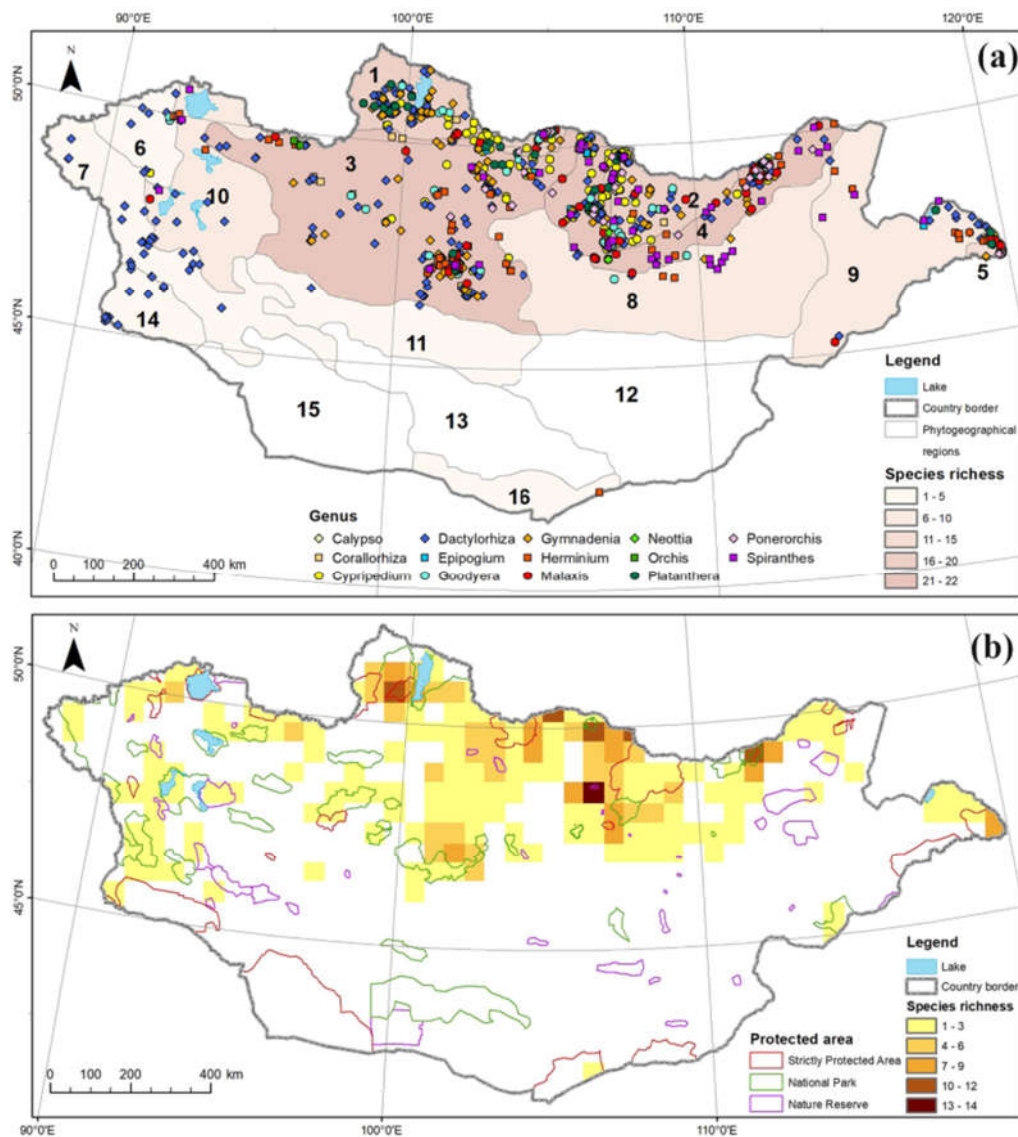


### 3.2. Species Richness and Distribution

We found 26 species of Orchidaceae belonging to 14 genera, in 13 phytogeographical regions of Mongolia (Figure 4a). The Khangai and Mongolian Dauria regions had the highest number of species, with 21 species each, followed by Khuvsgul (18 species), Khentii (16 species), and Foothills of Great Khingan (11 species). No orchids were found in the Trans-Altai Gobi, Gobi Altai, or the East Gobi, and the Alashan Gobi region had one orchid species, *Herminium alaschanicum*, which was found only in this region. In addition, *Dactylorhiza incarnata* subsp. *cruenta* was observed only in the Khangai region, and *Neottia puberula* was found only in the Foothills of Great Khingan. Four species were observed in only two regions. For instance, *Calypso bulbosa* was found in the Khentii, *Cypripedium ventricosum* in the Khuvsgul and *Orchis militaris* in the Khangai region. *Platanthera oligantha* was found only in the Khuvsgul and Khangai regions. *Dactylorhiza salina*, which was found in 12 phytogeographical regions, was the most widely distributed orchid species in Mongolia.

Based on the grid map of species richness, 155 cells had one to four orchid species, whereas only 33 cells from among the 715 cells had five or more species. Our results indicated that the area covered by orchids accounted for approximately 26% of the Mongolian territory. Almost all observations were distributed in the northern part of the country, particularly at latitudes higher than 45° N (Figure 4b). If we look closely at the localities with high orchid species richness (Figure 4b), 14 species were recorded within a single grid cell around the Noyon Mountain, along the borders of Mandal soum in Selenge province and Batsumber and Bornuur soums in Tuv province, which was the most orchid-rich area. Two grid cells each recorded the second highest number of species (11 species) observed. Both locations were near the Mongolian–Russian border, particularly in the north-eastern part of Khuder soum in Selenge province, and between Dadal soum in Khentii province and Bayan-Uul soum in Dornod province. These were followed by three cells with ten species, two in Selenge province, and one in the southern part of the Darkhad depression in Khuvsgul province. The grid cell with the highest number of orchid species overlapped with the Noyon Mountain nature reserve. However, the nature reserve has a smaller area than the grid cell; thus, not all species in the grid cell are within the protected area. Among the five cells with 10 to 11 species, one cell was partially included within a Strictly Protected Area and two cells were partially included in national parks (Figure 4b).

In terms of protection, 23 out of the 26 orchid species had at least one observation in a protected area of Mongolia (Figure 4b). For instance, the distribution areas of *Herminium alaschanicum* and *Calypso bulbosa* were found to be within protected areas, whereas that of *Cypripedium × ventricosum*, *Dactylorhiza incarnata* subsp. *cruenta* and *Neottia camtschatea* were not within any protected area, despite all these species having less than three observations each in our database. In addition, two observations of *Neottia puberula* were found within a protected area, and one observation was noted outside. *Corallorhiza trifida* and *Dactylorhiza fuchsii* had more than 50% of the total observations noted within protected areas, whereas the remaining 18 species had less than 50% of the total observations included in protected areas.



**Figure 4.** Species distribution pattern of Orchidaceae in Mongolia: (a) Species richness based on phytogeographical regions, with distribution points; 1–Khuvsgul, 2–Khentii, 3–Khangai, 4–Mongolian Dauria, 5–Foothills of Great Khingan, 6–Khovd, 7–Mongolian Altai, 8–Middle Khalkh, 9–East Mongolia, 10–Depression of Great Lakes, 11–Valley of Lakes, 12–East Gobi, 13–Gobi Altai, 14–Dzungarian Gobi, 15–Transaltai Gobi, 16–Alashan Gobi. (b) Species richness within protected areas based on grid cells.

#### 4. Discussion

Overall, Orchidaceae checklist was thoroughly amended based on species distribution in the phytogeographical regions of Mongolia [23,24]. Recently, a comprehensive checklist including 27 orchid taxa was compiled by Urgamal et al. [25]. However, significant revisions were needed because some species had to be added or omitted (see *Epipactis* and *Herminium*), as well as the scientific names of some taxa were changed. Therefore, we critically revised all orchid taxa based on herbaria, literature, and field observations, and provided 26 taxa distribution maps with photographs of 18 taxa (Figures 1–3; Appendix A). The present distribution of certain genera was compared to that of previous research, and five genera showed major changes according to our review. Hence, the selected genera are explained in detail below.

#### 4.1. Taxonomic Notes on Selected Genera

##### *Dactylorhiza* Sw.

*Dactylorhiza* is the most difficult genus among orchids to identify because of morphological plasticity, ongoing evolution, and wide hybridization; therefore, the status of accepted species changes continually [37,42]. Currently, six taxa have been reported in Mongolia [23–25,43], but the number of species may vary depending on the author. One of the most taxonomically problematic groups is ‘salina-aggregate’, which is represented in the current overview by two species, viz. *D. salina* s.str. and *D. umbrosa*. It should be noted that the boundaries between them are very obscure, and that both taxonomical concepts are accepted here and determinations of herbarium specimens used in the study should be viewed as only preliminary. An alternative approach may be to accept one species in the group, *D. salina* s.l., or to further subdivide the group into smaller taxa. Another taxonomical problem is *D. incarnata* subsp. *cruenta*, which may be viewed by some taxonomists as a hyperchromic variant of *D. incarnata* with dots on the leaves, which is taxonomically identical to *D. incarnata*. Hence, further comprehensive studies on this genus are required.

##### *Epipactis* Zinn.

In Mongolia, two species of *Epipactis*, *E. helleborine* and *E. palustris*, were reported for the western part by Averyanov [30]; however, herbarium information was not provided. Since 1994, several checklists of Mongolian flora have noted that *Epipactis* has been recorded in western Mongolia based on the above-mentioned source. However, we only found one herbarium specimens of *E. palustris* (Figure 3f) from the herbarium TK labeled as “collected within Mongolia.” When we revised the collection site, the locality fell outside Mongolia (in the territory of China), although not far from the Mongolian border. Additionally, Grubov [36] provided both species occurred in Tien Shan, East Siberia, and the Caucasus. Thus, both species were excluded from Urgamal et al. [25] according to the current study, but further findings of both species from western Mongolia are possible.

##### *Herminium* L.

In most of the literature, only one species, *H. monorchis*, has been reported in Mongolia [21,23,44]. Grubov [36] and Raskoti et al. [31] added one more species, *H. alashanicum* Maxim., (Figure 3h) after its type collection. The herbarium is located in the Alashan Gobi region of Mongolia, near the border with China. However, Efimov [45] mistakenly stated that its location was in China. Further study is needed in the Alashan Gobi region to confirm whether this species is extant in the country.

##### *Orchis* L.

In the past, *Orchis militaris* L. (Figure 3g) was noted only in the Noyon Mountain area in the Mongolian Dauria region [23]. More recently, this species has been recorded in several regions of Mongolia [25], and we found four locations in the Khentii, Mongolian Dauria, and Khangai regions (Figure A21). In addition, several herbarium specimens of *O. militaris* were identified as *Dactylorhiza* spp. in the country. The correct herbarium specimens of *O. militaris* are preserved in the LE, MW, and HAL herbaria.

##### *Spiranthes* Rich.

*Spiranthes amoena* (M.Bieb.) Spreng. has been observed in several regions of Mongolia [23,24]. Later, *S. amoena* was proven to be a synonym of *S. sinensis*, which is mentioned in the Conspectus of Mongolian flora [25]. More recently, Pace et al. [32] investigated the *Spiranthes sinensis* complex based on molecular and morphological differences among *Spiranthes* taxa worldwide. According to Pace et al. [32], Mongolian *S. sinensis* and *S. amoena* are clearly identified as *S. australis* with hairy and densely pubescent flowering stems (Figure 1d).

#### 4.2. National Red List Assessment

In the past, 16 species have been assessed according to the regional conservation status based on the most commonly used IUCN category, criterion B [9,28,29]. However, species distribution area sizes, such as EOO and AOO, were not estimated in the assessed species owing to limited distributional information. Therefore, we reassessed all orchid species based on more comprehensive collections, except *Cypripedium × ventricosum*, because of its hybrid status. In comparison to previous studies, some species belong to different categories (Table 2). For example, *Dactylorhiza fuchsii* was assessed as a critically endangered species with only one distribution point [28], but we found eight distribution points in the country, thus resulting in the species being as endangered (Figure A7).

Most Mongolian orchids co-occur in neighboring countries such as Russia and China [10,17], albeit with varying levels of threat status. For example, *Cypripedium guttatum* evaluated as a near threatened species in Mongolia, is considered an endangered species in China [10]. Similarly, *Calypso bulbosa* is critically endangered in Mongolia, whereas it is quite common in Russia [17]. Moreover, this species has not been observed in the wild in Mongolia over 10 years. Regardless of the co-occurrence with adjacent regions, we should give great consideration to the threatened species, which are valuable to Mongolian floral diversity.

#### 4.3. Species Richness Distribution

We analyzed the 970 georeferenced distribution records of 26 orchid species based on  $0.5^\circ \times 0.5^\circ$  grid cell size across 16 phytogeographical regions (Figure 4a,b). Mongolian orchid species richness is low in comparison to that in neighboring countries such as Russia (135 species [17]) and China (1582 species [10]), which might be explained by the relatively low intensity of field surveys, large size of unsettled land, and harsh continental climatic conditions. Our study revealed that the northern and north-eastern parts of the country have relatively diverse orchid flora compared to that in the western and southern regions of the country. This is certainly because of the optimum growth conditions for orchid species. In particular, orchids are constrained by edaphic environments and their relationships with mycorrhizal fungi and specialist pollinators [16,46]. The northern part of Mongolia is on the southern border of the Siberian boreal forest [47], and along the latitudinal gradient, precipitation decreases and temperature increases [48]. Therefore, northern and north-eastern Mongolia have a high number of orchid species compared to that in the arid steppes and deserts in the south and southeast.

Our results indicated that seven grid cells had a high diversity of orchids, primarily in the northern part of the country. In fact, most of the distribution areas were not well covered by protected areas. It should be noted that our findings were limited to orchid varieties; however, we did find many rare plants, particularly in the northern regions [26,49]. There are large-scale protected areas in the eastern steppe and southern Gobi of Mongolia, with the aim of protecting wild animals. However, the floral importance of this area is frequently overlooked. Therefore, concern for both wildlife and floral conservation simultaneously is critical, as they are integral parts of the same ecosystem. Through the establishment of protected areas, destruction of the habitat of dozens of taxa can be protected from activities such as mining, herb harvesting, and livestock grazing. Thus, we highlight the importance of conducting in-depth research on floral diversity and conservation gaps, especially in Mongolia's northern and central forest areas.

### 5. Conclusions

The present study provides valuable information on the orchid species richness of Mongolia, with a focus on current conservation status, grid distribution maps, and photo illustrations in the wild. We documented 26 orchid taxa in Mongolia, among which 12 species were threatened at the national level. Orchids are distributed mainly in the

northern, eastern, and central parts of Mongolia (Figure 4a,b). Despite the species diversity of orchids being not particularly rich, the importance of protection cannot be neglected.

**Author Contributions:** Conceptualization, S.B.; methodology, S.B., Z.T and S.V.; formal analysis, S.B., Z.T. and S.V.; resources, S.B., P.E., B.O., M.U., A.U., K.K. and T.N.; writing—original draft preparation, S.B.; writing—review and editing, K.O., S.V., P.E. and H.J.C.; supervision, B.O. and H.J.C.; project administration, H.J.C.; funding acquisition, H.J.C. All authors have read and agreed to the published version of the manuscript.

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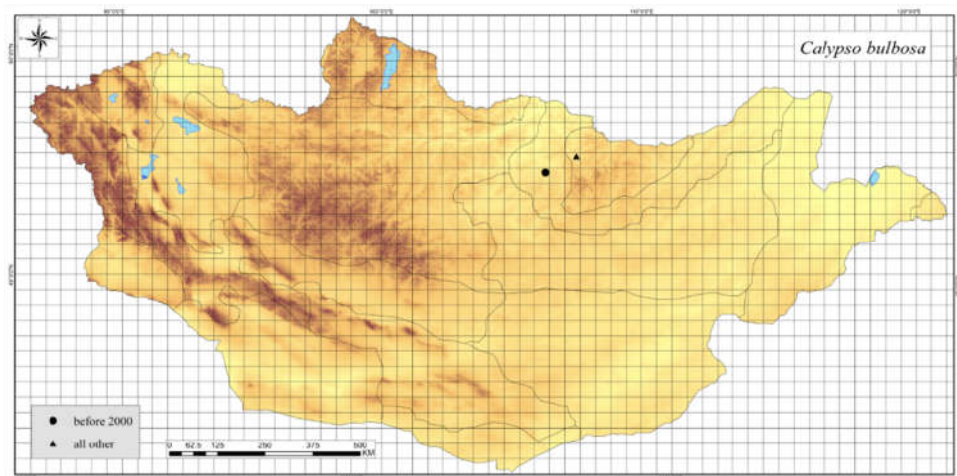
**Data Availability Statement:** All the data were obtained from herbaria, field surveys, and literature and are available from the first author on reasonable request.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

The grid distribution map of 26 orchid taxa in Mongolia. Data were mainly based on herbarium collections. Symbols are according to Table 1.



**Figure A1.** Distribution map of *Calypso bulbosa* in Mongolia.

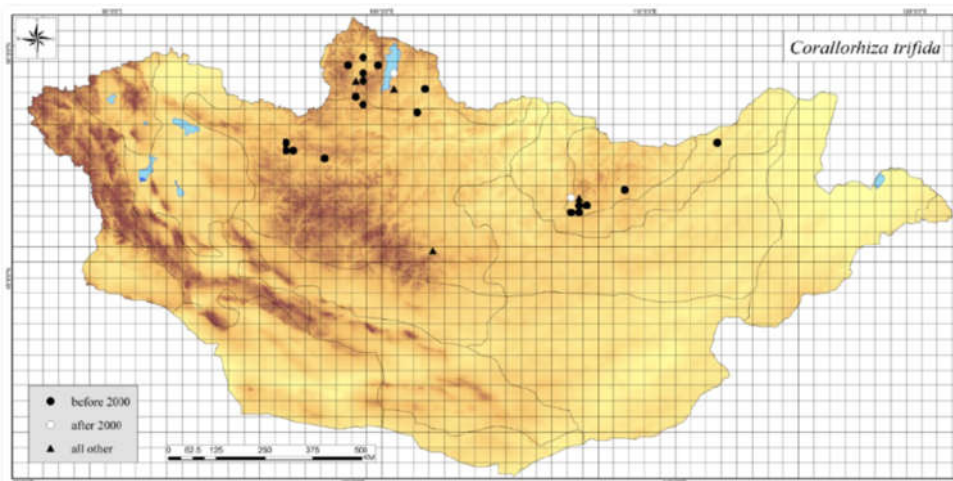


Figure A2. Distribution map of *Corallorhiza trifida* in Mongolia.

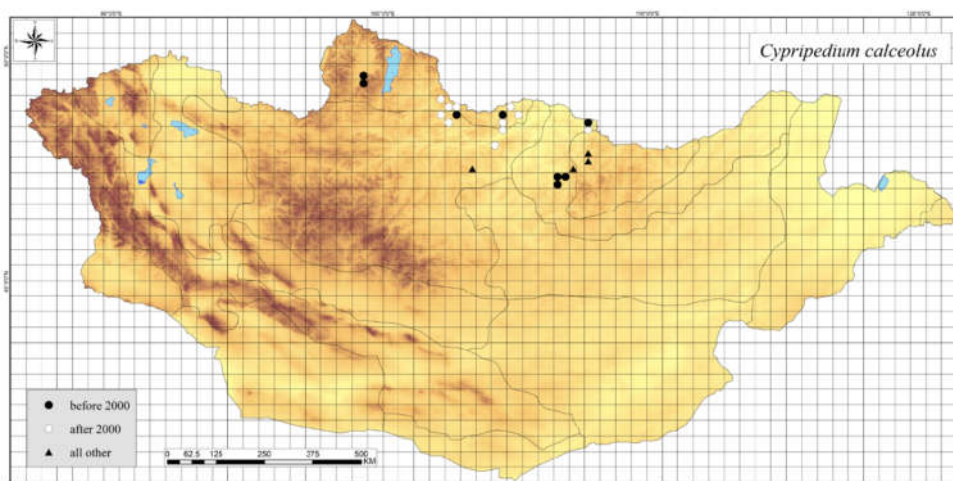


Figure A3. Distribution map of *Cypripedium calceolus* in Mongolia.

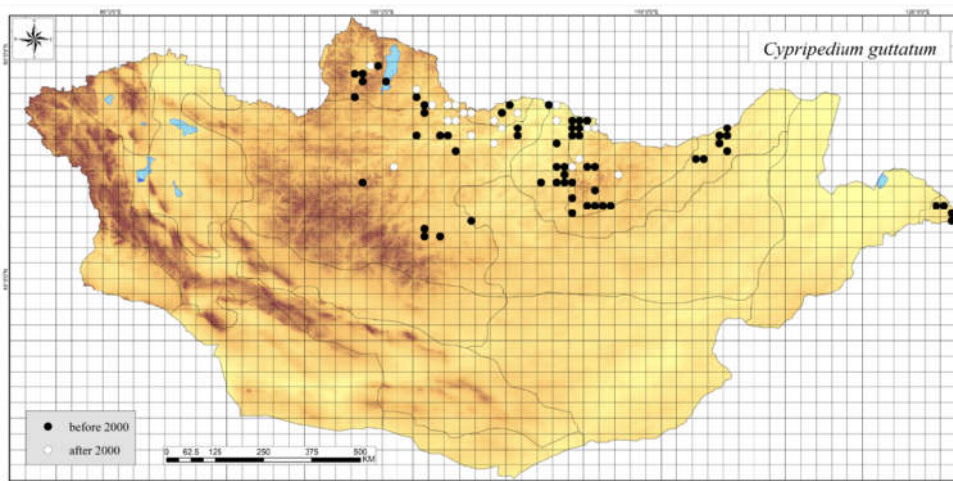


Figure A4. Distribution map of *Cypripedium guttatum* in Mongolia.

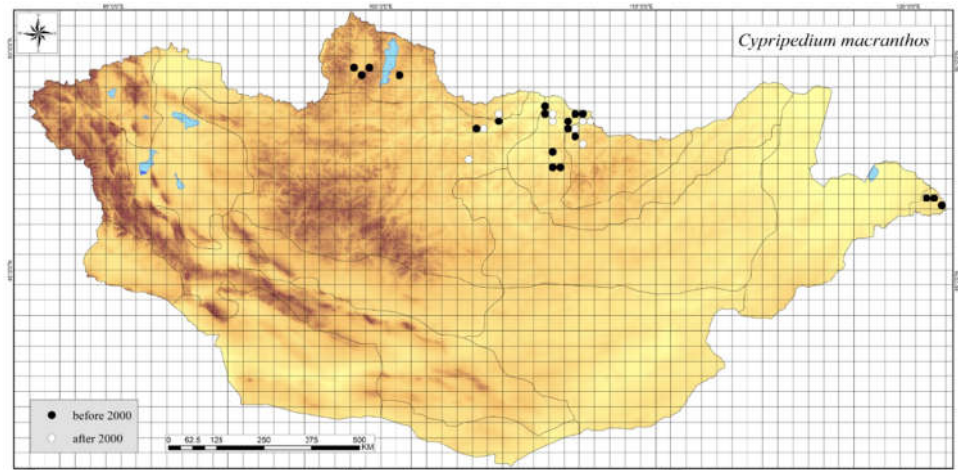


Figure A5. Distribution map of *Cypripedium macranthos* in Mongolia.

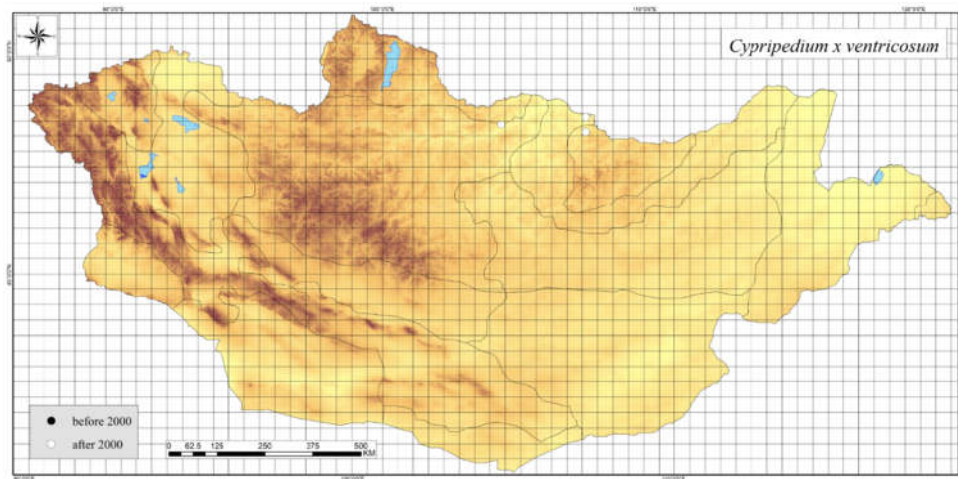


Figure A6. Distribution map of *Cypripedium x ventricosum* in Mongolia.

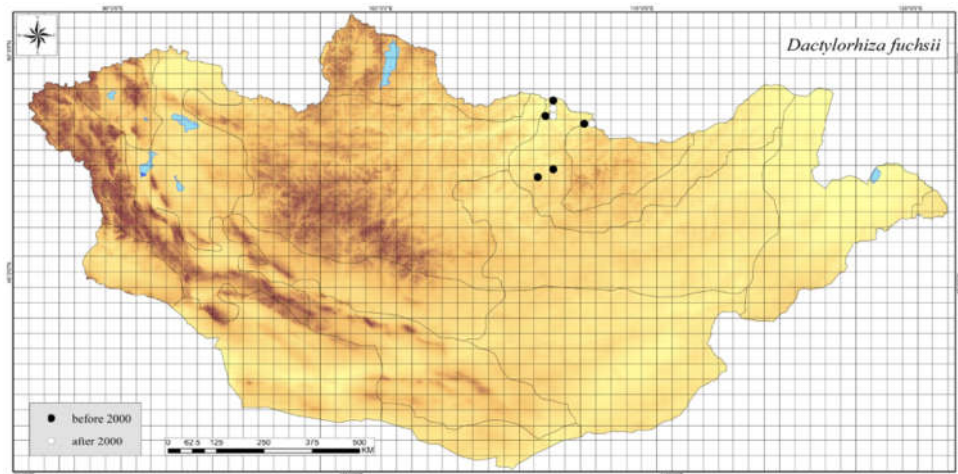


Figure A7. Distribution map of *Dactylorhiza fuchsii* in Mongolia.

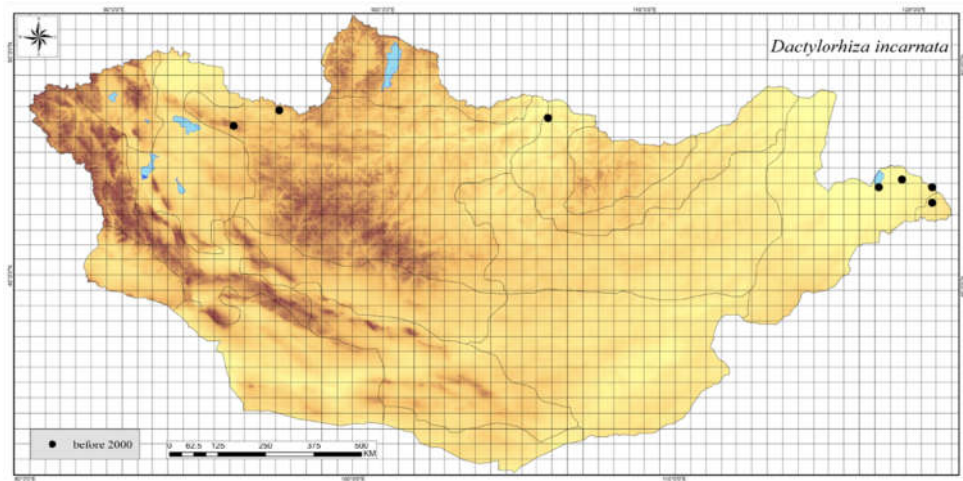


Figure A8. Distribution map of *Dactylorhiza incarnata* in Mongolia.

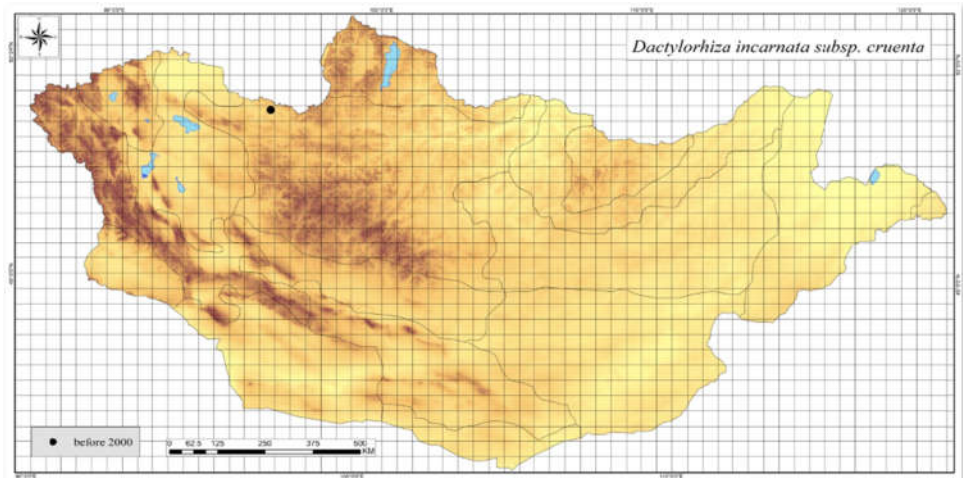


Figure A9. Distribution map of *Dactylorhiza incarnata* subsp. *cruenta* in Mongolia.

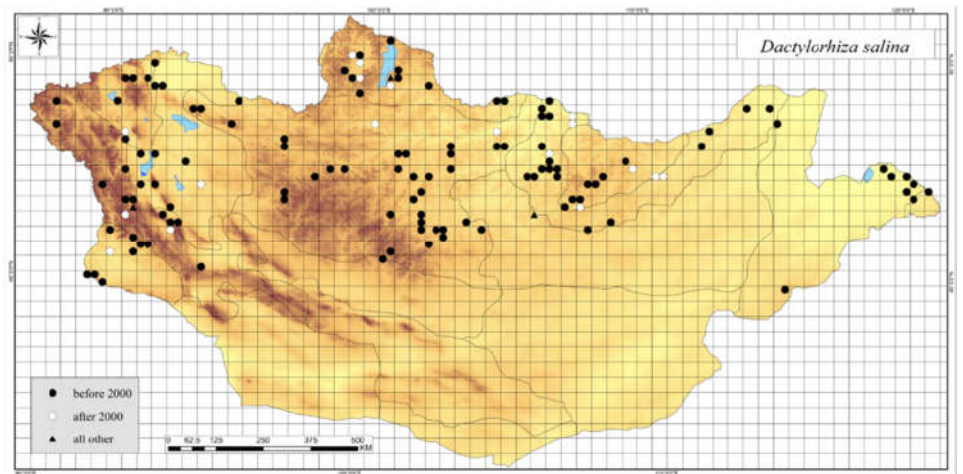


Figure A10. Distribution map of *Dactylorhiza salina* in Mongolia.



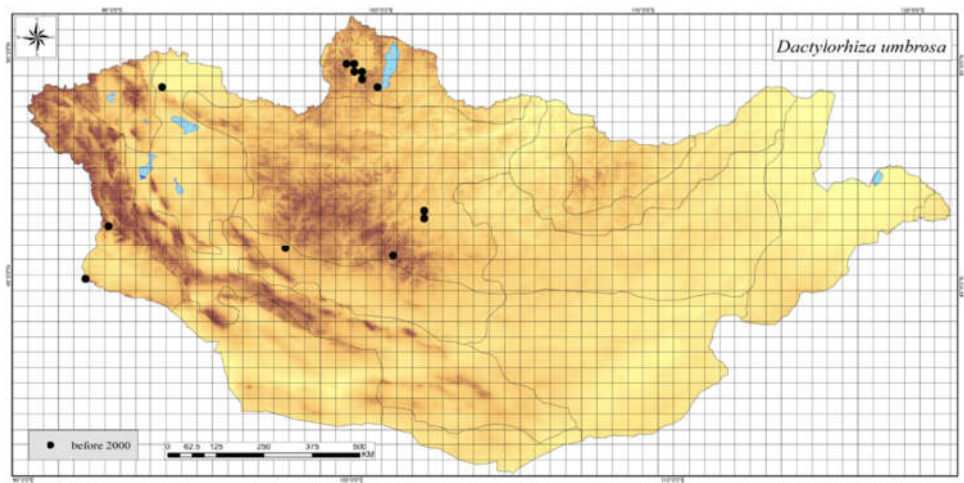


Figure A11. Distribution map of *Dactylorhiza umbrosa* in Mongolia.

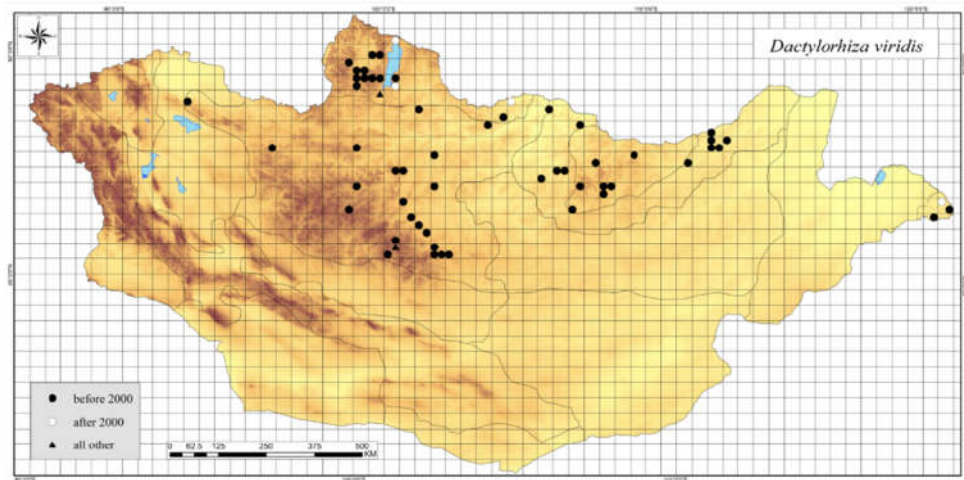


Figure A12. Distribution map of *Dactylorhiza viridis* in Mongolia.

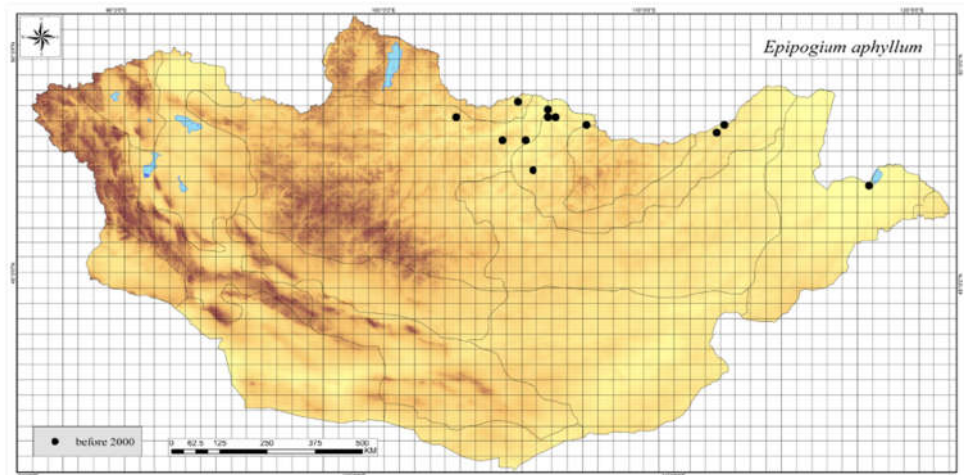


Figure A13. Distribution map of *Epipogium aphyllum* in Mongolia.

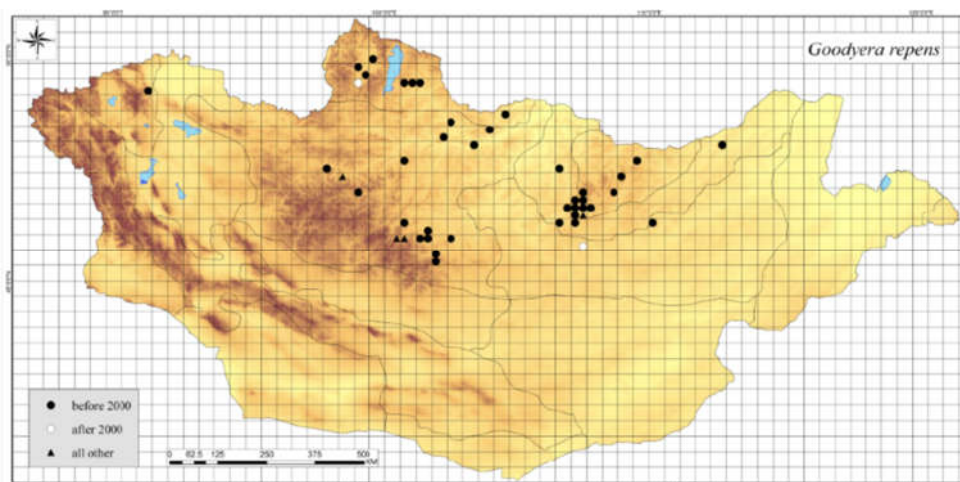


Figure A14. Distribution map of *Goodyera repens* in Mongolia.

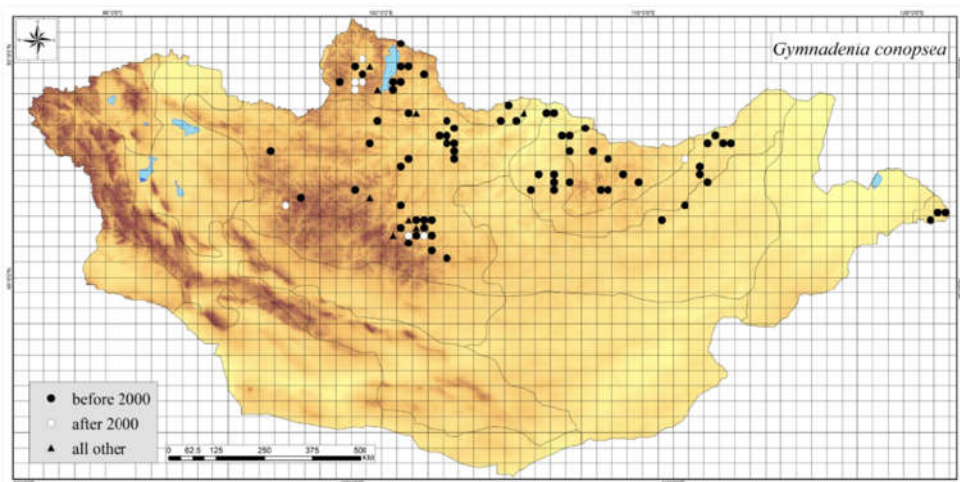


Figure A15. Distribution map of *Gymnadenia conopsea* in Mongolia.

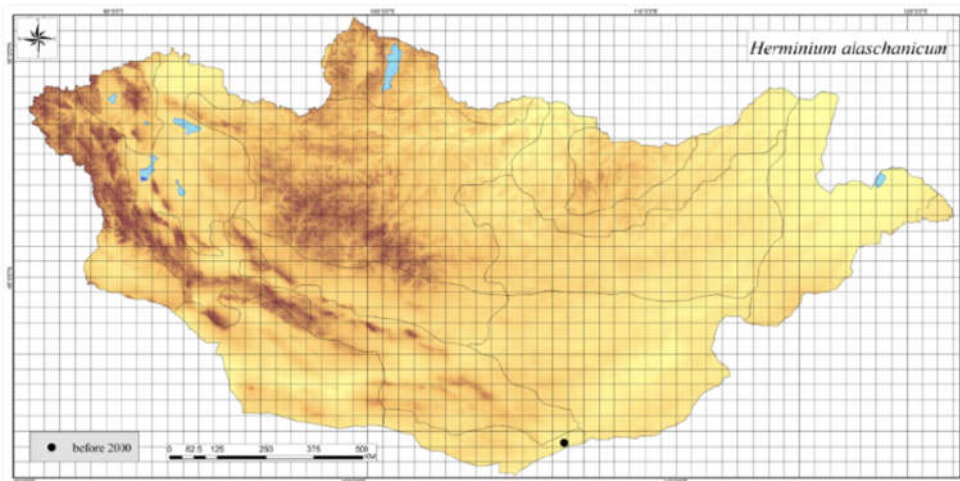


Figure A16. Distribution map of *Herminium alaschanicum* in Mongolia.

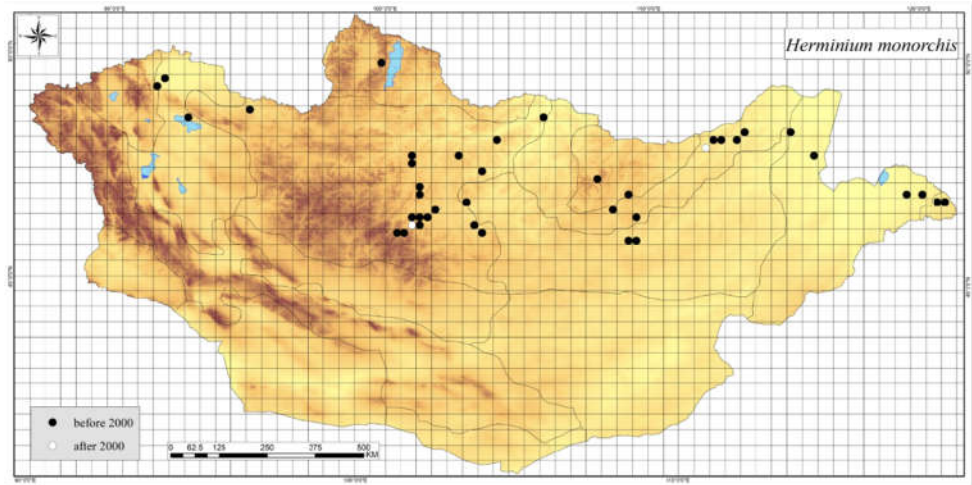


Figure A17. Distribution map of *Herminium monorchis* in Mongolia.

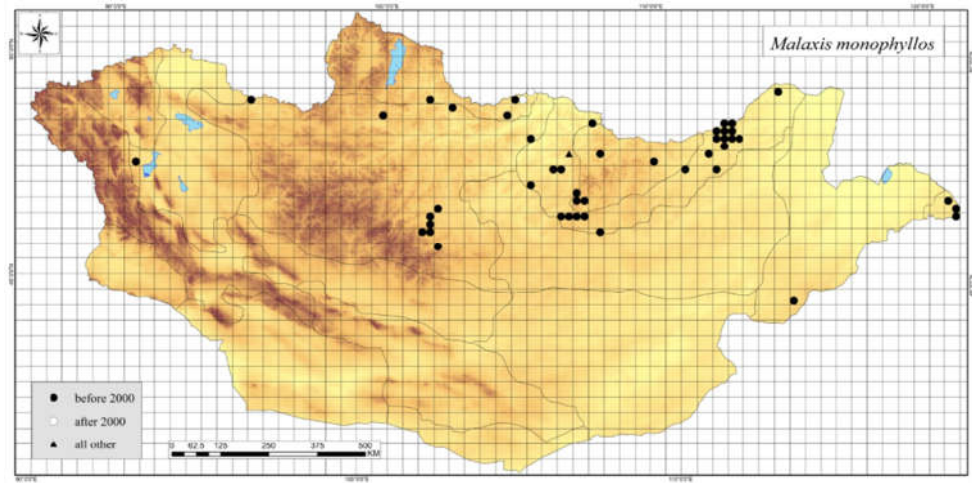


Figure A18. Distribution map of *Malaxis monophyllos* in Mongolia.

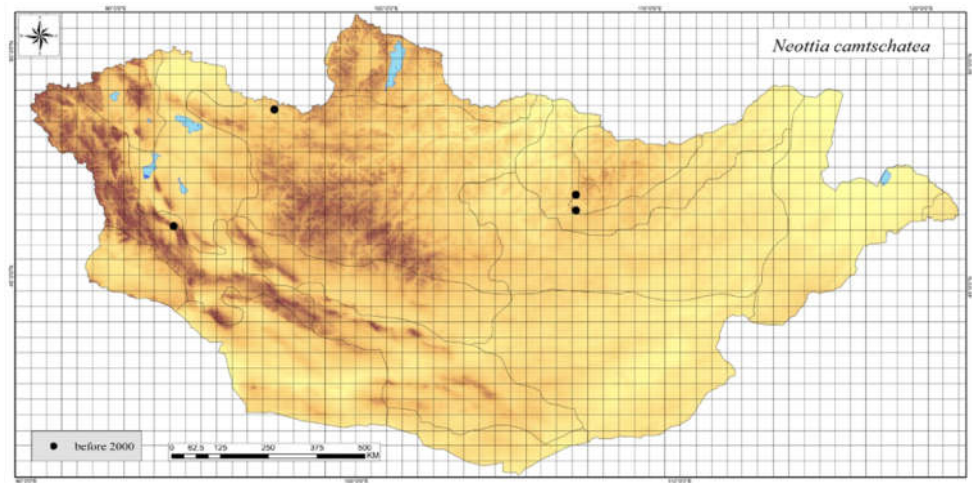


Figure A19. Distribution map of *Neottia camtschatea* in Mongolia.

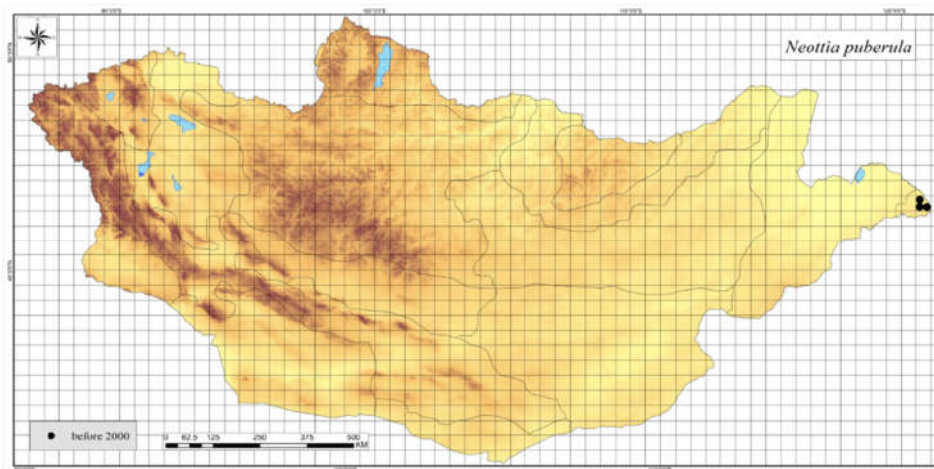


Figure A20. Distribution map of *Neottia puberula* in Mongolia.

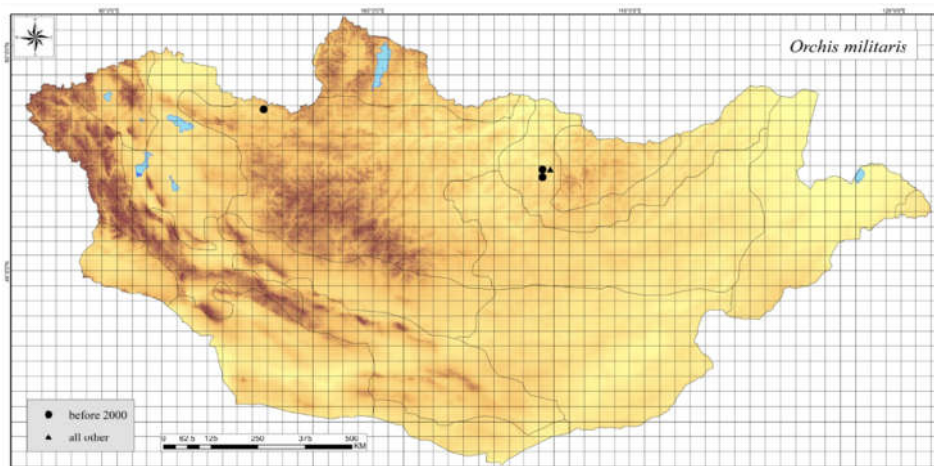


Figure A21. Distribution map of *Orchis militaris* in Mongolia.

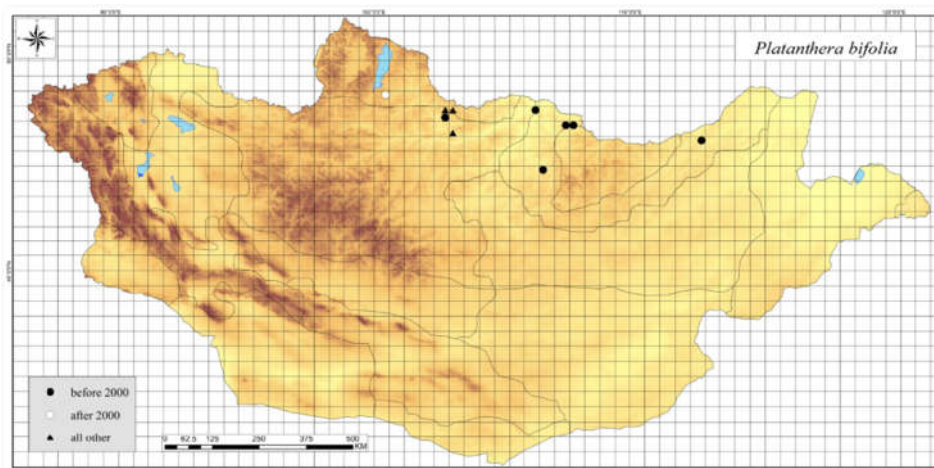


Figure A22. Distribution map of *Platanthera bifolia* in Mongolia.

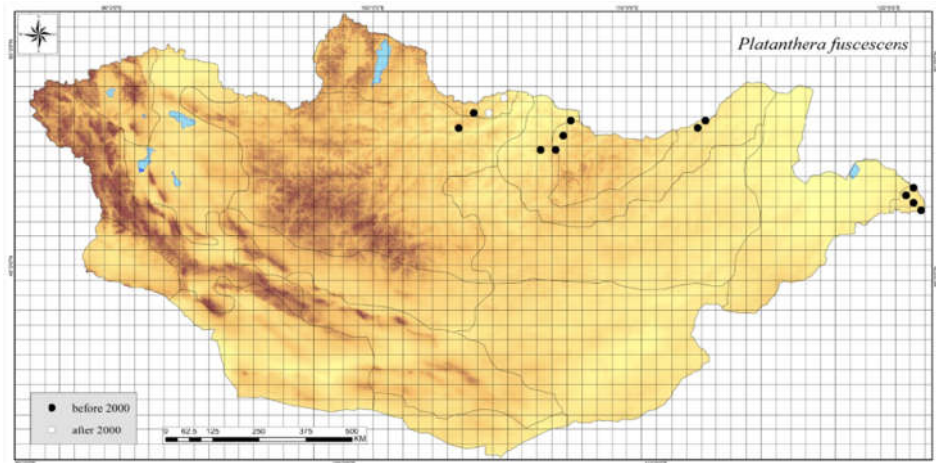


Figure A23. Distribution map of *Platanthera fuscescens* in Mongolia.

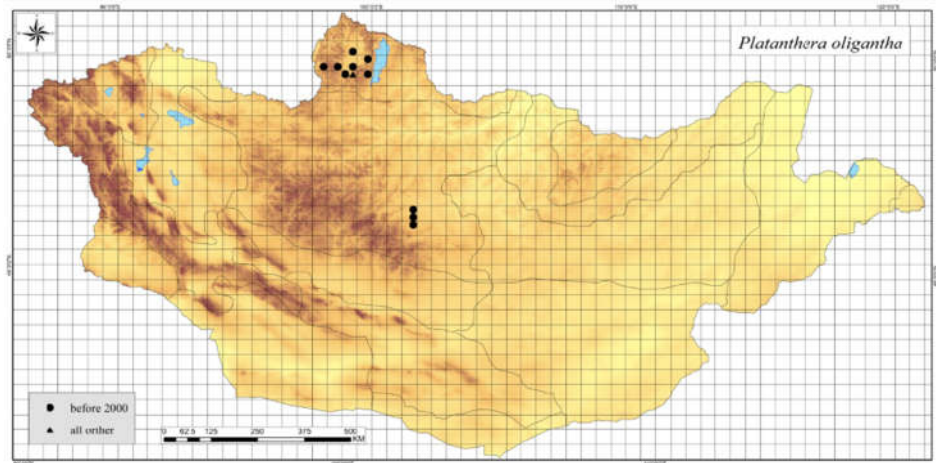


Figure A24. Distribution map of *Platanthera oligantha* in Mongolia.

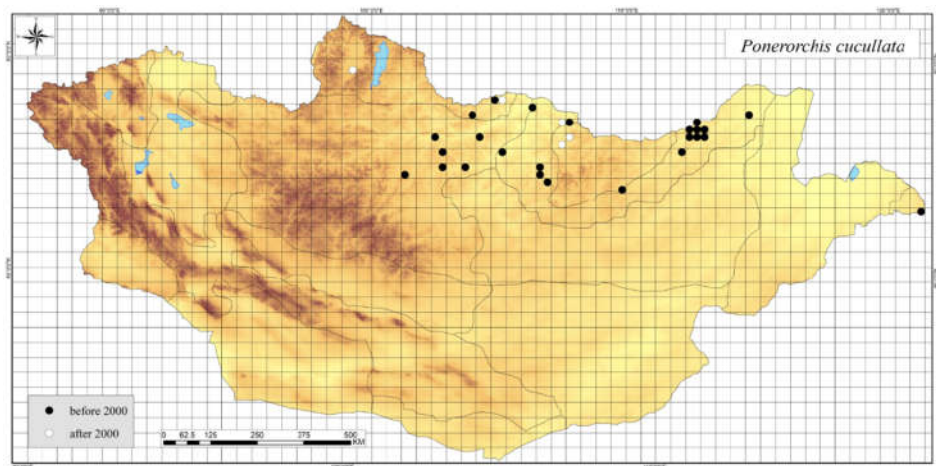


Figure A25. Distribution map of *Ponerorchis cucullata* in Mongolia.

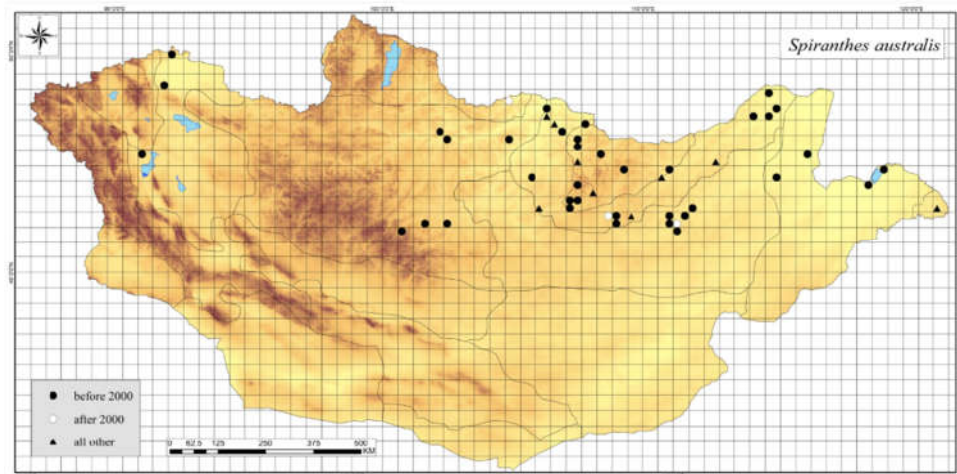


Figure A26. Distribution map of *Spiranthes australis* in Mongolia.

## References

- Fay, M.F. Orchid conservation: How can we meet the challenges in the twenty-first century? *Bot. Stud.* **2018**, *59*, 1–16, doi:10.1186/s40529-018-0232-z.
- Zizka, A.; Silvestro, D.; Vitt, P.; Knight, T.M. Automated conservation assessment of the orchid family with deep learning. *Conserv. Biol.* **2020**, *35*, 897–908, doi:10.1111/cobi.13616.
- Swartz, N.D.; Dixon, K.W. Terrestrial orchid conservation in the age of extinction. *Ann. Bot.* **2009**, *104*, 543–556, doi:10.1093/aob/mcp025.
- Chase, M.W.; Cameron, K.M.; Freudenstein, J.V.; Pridgeon, A.M.; Salazar, G.; van den Berg, C.; Schuiteman, C. An updated classification of Orchidaceae. *Bot. J. Linn. Soc.* **2015**, *177*, 151–174.
- Hassler, M. World Orchids. Synonymic Checklist and Distribution of the Orchids of the World. Available online: <https://www.worldplants.de/orchids/total-species-count> (accessed on 11 May 2021).
- IUCN 2019. The IUCN Red List of Threatened Species. Available online: <http://www.iucnredlist.org>. (accessed on 1 March 2020).
- Kreziou, A.; De Boer, H.; Gravendeel, B. Harvesting of salep orchids in north-western Greece continues to threaten natural populations. *Oryx* **2016**, *50*, 393–396, doi:10.1017/S0030605315000265.
- Kull, T.; Selgis, U.; Pecina, M.V.; Metsare, M.; Ilves, A.; Tali, K.; Sepp, K.; Kull, K.; Shefferson, R.P. Factors influencing IUCN threat levels to orchids across Europe on the basis of national red lists. *Ecol. Evol.* **2016**, *6*, 6245–6265.
- Oyuntsetseg, B.; Baasanmunkh, S.; Nyambayar, D.; Batkhuu, N.O.; Choi, H.J.; Chung, G.Y. *The Conservation Status of 100 Rare Plants in Mongolia*; Korea National Arboretum: Pocheon, Korea, 2018; p. 232.
- Liu, H.; Liu, Z.; Jin, X.; Gao, J.; Chen, Y.; Liu, Q.; Zhang, D.Y. Assessing conservation efforts against threats to wild orchids in China. *Biol. Conserv.* **2020**, *243*, 108484.
- Rankou, H.; Bilz, M. The IUCN Red List of Threatened Species. Available online: <http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T162021A43316125.en> (accessed on 15 April 2021).
- Jakubska-Busse, A.; Tsiftsis, S.; Śliwiński, M.; Křenová, Z.; Djordjević, V.; Steiu, C.; Kolanowska, M.; Efimov, P.; Hennigs, S.; Lustyk, P.; et al. How to Protect Natural Habitats of Rare Terrestrial Orchids Effectively: A Comparative Case Study of *Cypripedium calceolus* in Different Geographical Regions of Europe. *Plants* **2021**, *10*, 404, doi:10.3390/plants10020404.
- Khapugin, A.A.; Chugunov, G.G.; Vargot, E.V. *Cypripedium calceolus* (Orchidaceae) in central Russia: A case study for its populations in two protected areas in the Republic of Mordovia (Russia). *Lankesteriana* **2017**, *17*, 417–431, doi:10.15517/lank.v17i3.31577.
- Kolanowska, M.; Jakubska-Busse, A. Is the lady's-slipper orchid (*Cypripedium calceolus*) likely to shortly become extinct in Europe? Insights based on ecological niche modelling. *PLoS ONE* **2020**, *15*, e0228420, doi:10.1371/journal.pone.0228420.
- Zhang, Z.; Yan, Y.; Tian, Y.; Li, J.; He, J.-S.; Tang, Z. Distribution and conservation of orchid species richness in China. *Biol. Conserv.* **2015**, *181*, 64–72.
- Gaskett, A.C.; Gallagher, R.V. Orchid diversity: Spatial and climatic patterns from herbarium records. *Ecol. Evol.* **2018**, *8*, 11235–11245, doi.org/10.1002/ece3.4598.
- Efimov, P.G. Orchids of Russia: Annotated checklist and geographic distribution. *Nat. Conserv. Res.* **2020**, *5*, 1–18, doi:10.24189/ncr.2020.018.
- Juiling, S.; Sabah, U.M.; Leon, S.K.; Jumian, J.; Tsen, S.; Lee, Y.L.; Khoo, E.; Sugau, J.B.; Nilus, R.; Pereira, J.T.; et al. Conservation assessment and spatial distribution of endemic orchids in Sabah, Borneo. *Nat. Conserv. Res.* **2020**, *5*, 136–144.

19. Stipkova, Z.; Kindlmann, P. Orchid Extinction over the Last 150 Years in the Czech Republic. *Diversity* **2021**, *13*, 78, doi:10.3390/d13020078.
20. Tsiftsis, S.; Tsiripidis, I. Temporal and spatial patterns of orchid species distribution on Greece: Implications for conservation. *Biodivers. Conserv.* **2020**, *29*, 3461–3489.
21. Djordjević, V.; Tsiftsis, S.; Lakušić, D.; Jovanović, S.; Stevanović, V. Orchid species richness and composition in relation to vegetation types. *Wulfenia*, **2020**, *27*, 183–210.
22. Khapugin, A.A. A global systematic review on orchid data in protected areas. *Nat. Conserv. Res.* **2020**, *5* (Suppl. 1), 19–33.
23. Grubov, V.I. *Key to Vascular Plants of Mongolia*; Nauka: Leningrad, Russia, 1982; p. 503. (In Russian)
24. Gubanov, A.I. *Conspectus of Flora in Outer Mongolia*; Valang: Moscow, Russia, 1996; p. 136. (In Russian)
25. Urgamal, M.; Oyuntsetseg, B.; Nyambayar, D.; Dulamsuren, C. *Conspectus of the Vascular Plants of Mongolia*; Admon Printing: Ulaanbaatar, Mongolia, 2014; pp. 42–44.
26. Baasanmunkh, S.; Oyuntsetseg, B.; Oyundelger, K.; Khaliunaa, K.; Urgamal, M.; Batkhoo, N.-O.; Shiga, T.; Chung, G.Y.; Choi, H.J. Contribution to the knowledge on the flora of northern Mongolia. *J. Asia. Pac. Biodivers.* **2019**, *12*, 643–660, doi:10.1016/j.japb.2019.08.009.
27. Urgamal, M.; Oyuntsetseg, B. *Atlas of the Endemic Vascular Plants of Mongolia*; Bembi San: Ulaanbaatar, Mongolia, 2017.
28. Nyambayar, D.; Oyuntsetseg, B.; Tungalag, R. *Mongolian Red List and Conservation Action Plans of Plants*; Admon Printing: Ulaanbaatar, Mongolia, 2011; p. 183.
29. Urgamal, M.; Oyuntsetseg, B.; Tungalag, R.; Gundegmaa, V.; Oyundari, C.; Tserendulam, C.; Munkh-Erdene, T.; Solongo, S. *Mongolian Plants Red List 2*; Bembi San: Ulaanbaatar, Mongolia, 2019; p. 230. (In Mongolian)
30. Averyanov, L.V. Review of the species of the family Orchidaceae in the Caucasus flora. *Bot. Zhur.* **1994**, *79*, 108–127.
31. Raskoti, B.B.; Schuiteman, A.; Jin, W.T.; Jin, X.H. A taxonomic revision of *Herminium* L. (Orchidoideae, Orchidaceae). *PhytoKeys* **2017**, *79*, 1–74, doi:10.3897/phytokeys.79.11215.
32. Pace, M.J.; Cameron, K.M.; Frericks, J.; Giraldo, G.; Lehnebach, C.A. Illuminating the systematics of the *Spiranthes sinensis* species complex (Orchidaceae): Ecological speciation with little morphological differentiation. *Bot. J. Linn. Soc.* **2018**, *189*, 36–62, doi:10.1093/botlinnean/boy072.
33. Efimov, P.G. A revision of *Platanthera* (Orchidaceae; Orchidoideae; Orchideae) in Asia. *Phytotaxa* **2016**, *254*, 001–233.
34. Thiers, B. Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff. New York Botanical Garden's Virtual Herbarium. Available online: <http://sweetgum.nybg.org/ih/> (accessed 1 December 2020).
35. Rilke, S.; Najmi, U.; Schnittler, M. Contributions to 'E-Taxonomy' – A virtual approach to the flora of Mongolia (FloraGREIF). *Feddes. Repert.* **2013**, *123*, 219–232, doi:10.1002/fedr.201200013.
36. Grubov, V.I. *Plants of Central Asia: Plant Collection from China and Mongolia*; CRC Press: Boca Raton, Florida, USA, 2003; Volume 7, p. 186, doi:10.1201/9781482279764.
37. Efimov, P.G.; Phillipov, E.G.; Krivenko, D.A. Allopolyploid speciation in Siberian *Dactylorhiza* (Orchidaceae, Orchidoideae). *Phytotaxa* **2016**, *258*, 101–120, doi:10.11646/phytotaxa.258.2.1.
38. IUCN. Guidelines for Using the IUCN Red List Categories and Criteria; Version 14; Prepared by the Standards and Petitions Subcommittee. 2019. Available online: <https://www.iucnredlist.org/resources/redlistguidelines> (accessed on 15 August 2020).
39. Dauby, G.; Stévant, T.; Droissart, V.; Cosiaux, A.; Deblauwe, V.; Simo-Droissart, M.; Sosef, M.S.M.; Lowry, P.P.; Schatz, G.E.; Gereau, R.E.; et al. ConR: An R package to assist large-scale multispecies preliminary conservation assessments using distribution data. *Ecol. Evol.* **2017**, *7*, 11292–11303, doi:10.1002/ece3.3704.
40. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2016. Available from: <https://www.R-project.org/> (accessed 24 December 2020).
41. Esri. *ArcGIS Desktop: Release 10.2*; Environmental Systems Research Institute: Redlands, CA, USA, 2012.
42. Pillon, Y.; Fay, M.F.; Shipunov, A.B.; Chase, M.W. Species diversity versus phylogenetic diversity: A practical study in the taxonomically difficult genus *Dactylorhiza* (Orchidaceae). *Biol. Conserv.* **2006**, *129*, 4–13, doi:10.1016/j.biocon.2005.06.036.
43. Baasanmunkh, S.; Oyuntsetseg, B.; Oyundari, C.; Oyundelger, K.; Urgamal, M.; Darikhand, D.; Soninkhishig, N.; Nyambayar, D.; Khaliunaa, K.; Tsegmed, Z.; et al. The vascular plant diversity of Dzungarian Gobi in western Mongolia, with an annotated checklist. *Phytotaxa* **2021**, *501*, 1–55, doi:10.11646/phytotaxa.501.1.1.
44. Shukherdorj, B.; Shiga, T.; Batlai, O.; Wesche, K.; Ritz, C.M.; Khurelbaatar, K.; Kim, J.Y.; Jo, H.J.; Nyam-Osor, B.; Chung, G.Y.; et al. Contribution to the knowledge on the flora of Numrug Strictly Protected Area and some parts of East Mongolia. *J. Asia. Pac. Biodivers.* **2019**, *12*, 284–301, doi:10.1016/j.japb.2019.01.005.
45. Efimov, P.G. Additions to the orchidaceous part of the "Catalogues of the type specimens of the vascular plants" from Central and East Asia, Siberia and the Russian Far East kept in the Herbarium of the Komarov Botanical Institute (LE). *Novosti. Sist. Plant. Vasc.* **2018**, *49*, 42–50.
46. McCormick, M.K.; Jacquemyn, H. What constrains the distribution of orchid populations? *New Phytol.* **2014**, *202*, 392–400.
47. Gunin, P.D.; Vostokova, E.A.; Dorofeyuk, N.I.; Tarasov, P.E.; Black, C.C. *Vegetation Dynamics of Mongolia*; Kluwer Academic Publishers: The Dordrecht, The Netherlands; Boston, MA, USA; London, UK, 1999; p. 238.
48. Batima, P.; Natsagdorj, L.; Gombluudev, P.; Erdenetsetseg, B. Observed climate change in Mongolia. *Assess. Imp. Adapt. Clim. Chang. Work Paper* **2005**, *12*, 1–25.
49. Biazrov, L.G.; Ganbold, E.; Gubanov, I.A.; Ulziikhutag, N. *Flora of Khangaya*; Nauka: Leningrad, Russia, 1989; 191p. (In Russian)