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Floristic composition and plant diversity in distribution areas of native species congeneric with *Betula halophila* in Xinjiang, northwest China

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Abstract

Betula halophila, a wild plant with extremely small populations, is endemic to Xinjiang, northwest China. Its wild populations have declined severely in the field. Understanding the patterns of floristic composition where congeneric species of *B. halophila* are distributed and their determinants is a necessary step to restore the wild populations. Based on literature records, specimen information, shared public data and field survey data, the patterns of floristic composition, diversity and environmental conditions of seed flora within the distribution areas of five native species (i.e. *B. tianschanica*, *B. microphylla*, *B. pendula*, *B. rotundifolia* and *B. humilis*), congeneric with *B. halophila*, were examined. The results are as follows. (1) There were 3013 species, 693 genera and 108 families of seed plants in the distribution area of these congeneric species of *B. halophila*, which accounted for 86.16%, 94.54% and 93.91% of the total seed plants in Xinjiang, respectively. (2) The family composition of seed flora in the distribution area of these congeneric species of *B. halophila* was mainly cosmopolitan; the genus composition of seed flora was dominated by temperate, mainly of northern temperate and Mediterranean components. (3) There are no significant differences existing in plant richness amongst the areas where each of the five congeneric species (*B. tianschanica*, *B. microphylla*, *B. pendula*, *B. rotundifolia* and *B. humilis*) are distributed. (4) The influence of climate factors on species richness is significant across the whole distribution areas of the *Betula* genus, while the main environmental factors determining species richness are different amongst distribution areas of different species. Climate factors impacted significantly on species richness in distribution areas of tree species, but not in distribution areas of shrub species. This study provides a preliminary guideline for the conservation of *B. halophila*, a wild plant with extremely small populations in the field.

Keywords

Betula, congeneric species, geographic elements, richness, wild plant with extremely small populations

Introduction

Betula halophila, a deciduous shrub species in the genus *Betula* of the family Betulaceae, is an endangered and salt-tolerant plant, which is distributed only in Xinjiang in northwest China. In 1999, the species is firstly listed as one of the key protected wild plants of China with a second-class protection level (State Forestry Administration and Ministry of Agriculture 1999). In 2011, the species was listed as one of the 120 wild plants with extremely small populations in China (State Forestry Administration 2011). The species was firstly found in Yanchi Town, Altay City, Xinjiang in 1956 (Xinjiang Altay Forestry Institute, Xinjiang Forestry Academy 2010). No one has paid attention to it since then. Until 1996, the outstanding salt-tolerance character of this species has attracted researchers and then it aroused great interest of researchers again. In 2000 and 2001, experts carried out ex situ conservation on some survival individuals of this species in the field and transplanted them into the plant garden of the Academy of Forestry in Xinjiang (Xinjiang Altay Forestry Institute, Xinjiang Forestry Academy 2010). In 2003, some other wild individuals of this species suffered serious flooding. After that, the relevant researchers found no trace of this species in field.

Betula genus, belonging to Betulaceae, plays an important role in the flora and vegetation composition of Xinjiang. *Betula* is an essential part of the typical mountain broad-leaved forest in Xinjiang. There is a close relationship between the small leaf broad-leaved forest and the typical mountain coniferous forest in Xinjiang. *Betula* genera in Xinjiang include six species (*B. tianschanica*, *B. microphylla B. pendula*, *B. rotundifolia*, *B. humilis* and *B. halophila*) (Editorial Committee of Flora Xinjiangensis 1992). These six species are mainly distributed in the mountains of northern Xinjiang, including Altay, Tianshan and Western Junggar. Amongst them, *B. tianshanensis* is mainly distributed in Tianshan Mountain and the other five species are mainly distributed in the Altai mountain area. Only *B. halophila* is restricted in Xinjiang and occurred in Yanchi Town of Altai mountain area. *B. pendula* and *B. tianschanica* are the pioneer species of typical mountain forest spruce in Xinjiang. They play an important role in the natural regeneration of spruce community. In addition, all species of *Betula* within Xinjiang mostly distribute in Tianshan Mountain and Altai Mountain. The diversity hotspots of seed plants of Xinjiang are mainly located in both of these two mountains (Huang et al. 2018). Therefore, the main distribution area of *Betula* in Xinjiang is consistent with the diversity distribution centre of plant species in Xinjiang.

Researchers have done a lot of research on all species of *Betula* native in Xinjiang. These works are mainly related to taxonomy, phylogeny and physiology. The systematic classification of *Betula* in Xinjiang has always been controversial (Wang et al. 2016). *B. halophila* often forms salt crystals on the surface of the body to reduce the content of Ca^{2+} ion in the body and cope with the salt-stress environment (Zhang et al. 2009). The in-depth research has also focused on the salt-tolerance mechanism of the species (Shao et al. 2018). This species usually reduces the effect of stress by regulating its own osmotic substances, but this ability is very limited (Li et al. 2009). In addition, some research has been carried out on the intraspecific biomass allocation (Zhang et al. 2017), tree ring response to climate (Zhang et al. 2015) and intraspecific ISSR analysis (You et al. 2017) about its congeneric species. These studies provide an important basis for further understanding of the biological characteristics of *Betula* in Xinjiang, but the references for the ecological characteristics of these species are very limited.

The formation of flora is a comprehensive reflection of the evolution and temporal and spatial distribution of the flora in a certain natural historical environment. The flora of a specific region not only reflects the causal relationship between the total plants and the environment in the region, but also reflects the evolution of the flora in the geological history (Takhtajan1969; Wu et al. 2011). At the same time, flora is the main component of the biosphere, the first producer and the most active factor of capacity exchange and material cycle in ecosystem. Flora is the entity of vegetation, which is the reflection of natural geographical environment and the verification of environmental change (Wang 1992). Nowadays, biodiversity conservation is one of the top topics focused on by ecologists and biogeographers. It is closely related to flora (Chen et al. 2014; Weigelt et al. 2020; Wu 2004). In the study and application of basic theories, such as formation mechanism (Mienna et al. 2019) and change prediction of regional species diversity (Bruelheide et al. 2020), evaluation and protection of rare and endangered species (Phillips et al. 2011; Zhang et al. 2014), biodiversity evaluation, construction and planning of natural reserves, the floristic regionalisation and flora characteristics have played important roles, both in theory and practice (Wu 2004).

Arid regions account for 38–41% of the global land area. Compared with other regions and ecosystems, arid ecosystems are very sensitive to climate change and human activities (Reynolds et al. 2007; Maestre et al. 2015). Xinjiang, located in the hinterland of Eurasia, is a typical arid climate area with mountains and also breeds rich and unique biodiversity resources. The arid climate conditions lead to the salinisation of the soil and make it increasingly problematic (Wei and Xu 2005). Furthermore, with the rapid development of modern agriculture in oases, the degree of salinisation is still increasing. Therefore, Xinjiang has become a large area where soil salinisation is widely distributed (Tian et al. 2000). This is a great potential threat to the natural vegetation and species diversity of Xinjiang. Therefore, it is very important to strengthen the study of the adaptability of natural vegetation to salinisation. Research on the protection of salt-tolerant and alkali-resistant plants plays an important role in the protection of biodiversity in Xinjiang. Many plants in the birch family have strong salt tolerance and adapt to the special environment with a harsh environment (Yang et al. 2006). Amongst them, the most salt-tolerant is *B. halophila*, whose salt resistance is three times that of common birch species and ten times that of non-birch species (Wang 2003).

B. halophila is a typical wild plant with extremely small populations, which can provide important genetic resources for the cultivation of salt resistant varieties. However, the wild population of this species has not been found for more than ten years. In order to rescue and restore the populations of this species, the most important is to ensure the preservation of this genetic resource as early as possible. In order to expand the existing population size of this species as much as possible, we hope to expand the population number by adopting the way of near natural re-introduction of seedlings, so as to provide a rational basis for fast restoration of the populations. Based on the distribution data of congeneric species of *B. halophila*, we compared the floristic and diversity characteristics of floras within distribution areas of these species and assessed the main factors affecting the diversity patterns of their floras of these congeneric species of *B. halophila* in Xinjiang. We hope our study can provide a scientific guideline for the conservation of *B. halophila*, a wild plant with extremely small populations.

Materials and methods

Study area

Xinjiang is located in the hinterland of Eurasia (34°25'~ 49°10'N, 73°40'~ 96°18'E), with a total area of about 1.6×10^6 km^2, accounting for about one sixth of China's total land area and is the largest provincial administrative unit in China. Xinjiang has a complex terrain with a typical geomorphic pattern of "three mountains and two basins". From north to south, these are Altai Mountains, Junggar Basin, Tianshan Mountains, Tarim Basin and Kunlun Mountains (Mansuer 2012). Xinjiang has a typical continental climate with an annual average temperature of 4–14 °C and an annual average precipitation of about 150 mm. It is characterised by drought, little rain, severe winter and large temperature difference between day and night (Yao et al. 2015). Due to the complex topography and remarkable climate change, Xinjiang has developed a unique floristic composition (Xinjiang Investigation Group of Chinese Academy of Sciences 1978). Although the number of seed plant species in Xinjiang is far less than that in many provinces or regions of China, the proportion of endemic plants in Xinjiang is relatively higher than those in other provinces and regions. Amongst all the provinces in China, Taiwan has the highest proportion of endemic plants of 78%, followed by Xinjiang, with that of 73% (Huang 2010). The flora of Xinjiang mainly belongs to the Central Asia flora, which is quite different from other provinces or regions in China (Takhtajan 1969). Birch plants are essential components of small leaf broad-leaved forest in the mountainous areas of Xinjiang (Xinjiang Investigation Group of Chinese Academy of Sciences 1978). It is also an important pioneer tree species in the succession of mountain forest vegetation (Chen 1999). Birch plants in Xinjiang are mainly distributed in the Altai Mountains, Junggar Basin, western Junggar Mountains and the northern and southern slopes of Tianshan Mountains.

Data collection

Based on a large number of herbarium specimens (http://www.cvh.org.cn/), a list of Chinese seed plant species and distribution information at provincial level (Wu et al. 1994–2012) and other literature sources that mainly included *Flora Xinjiangensis* (Editorial Committee of Flora Xinjiangensis 1992–2011), A Primer of *Flora Xinjiangensis* (Editorial Committee of Flora Xinjiangensis 2014), *Sylva Xinjiangensis* (Yang 2012), *Desert Plants in China* (Lu et al. 2012) and *Rare Endangered Endemic Higher Plants in Xinjiang of China* (Yin 2006), we identified five congeneric species of *B. halophila* occurring in Xinjiang. These five species are *B. tianschanica*, *B. microphylla B. pendula*, *B. rotundifolia* and *B. humilis*. Combining the altitude range with the geographic distribution of all seed plant species occurring in Xinjiang and integrating data of field investigation in the past 10 years (2008–2018), we established a dataset of seed plants distribution in Xinjiang with a spatial unit of 50 km × 50 km (Huang et al. 2018). Based on this dataset, we extracted a subset of distribution data of Xinjiang seed plants, known as the distribution dataset of *Betula* plants in Xinjiang, according to distribution of these five congeneric species of *B. halophila* with a spatial unit of 50 km × 50 km (Fig. 1a–f). The flora of *Betula* in Xinjiang is distributed within four floristic regions (Fig. 1g), i.e. Altai region (IA2), Tianshan region (IA3), Junggar region (IIC5) and Kashgar region (IIC6) by referring to the Floristic Geography of Seed Plants in China (Wu et al. 2011). All species of *Betula* native in Xinjiang are distributed mostly in north Xinjiang, mainly in Tianshan Mountains, Altai Mountains and Junggar Basin (Fig. 1h). Geographic elements of families and genera are collected by referring to Areal-Types of Seed Plants and Their Origin and Differentiation (Wu et al. 2006). Amongst the five species, *B. tianschanica*, *B. microphylla* and *B. pendula*, are tall trees and *B. rotundifolia* and *B. humilis* are shrubs. Climate data are obtained from the data sharing platform of Worldclim Database (http://www.worldclim.org/). The mean annual evapotranspiration data are obtained from the atlas of the biosphere data sharing platform (https://library.McMaster.Ca/maps/geospatial?Location=89).

Data analysis

In this study, species richness (*S*) was used to indicate species diversity. In order to compare the species composition of different flora and different species distribution areas, the Sørensen similarity coefficient of species composition in different flora areas was calculated (Magurran 1988). The formula of this coefficient is as follows: $SI = 2c / (a + b)$, where *SI* is the Sørensen index, *a* and *b*, respectively, the number of species in two species distribution areas, only in one species distribution area and *c* represents the number of species shared by two species distribution areas. The proportions of geographical elements of family and genus are directly calculated by the number of families and genera per type in total families and genera in species distribution areas. Base on the spatial unit of 50 km × 50 km, the comparative analysis of plant richness in different species distribution areas and the relationship between species richness and

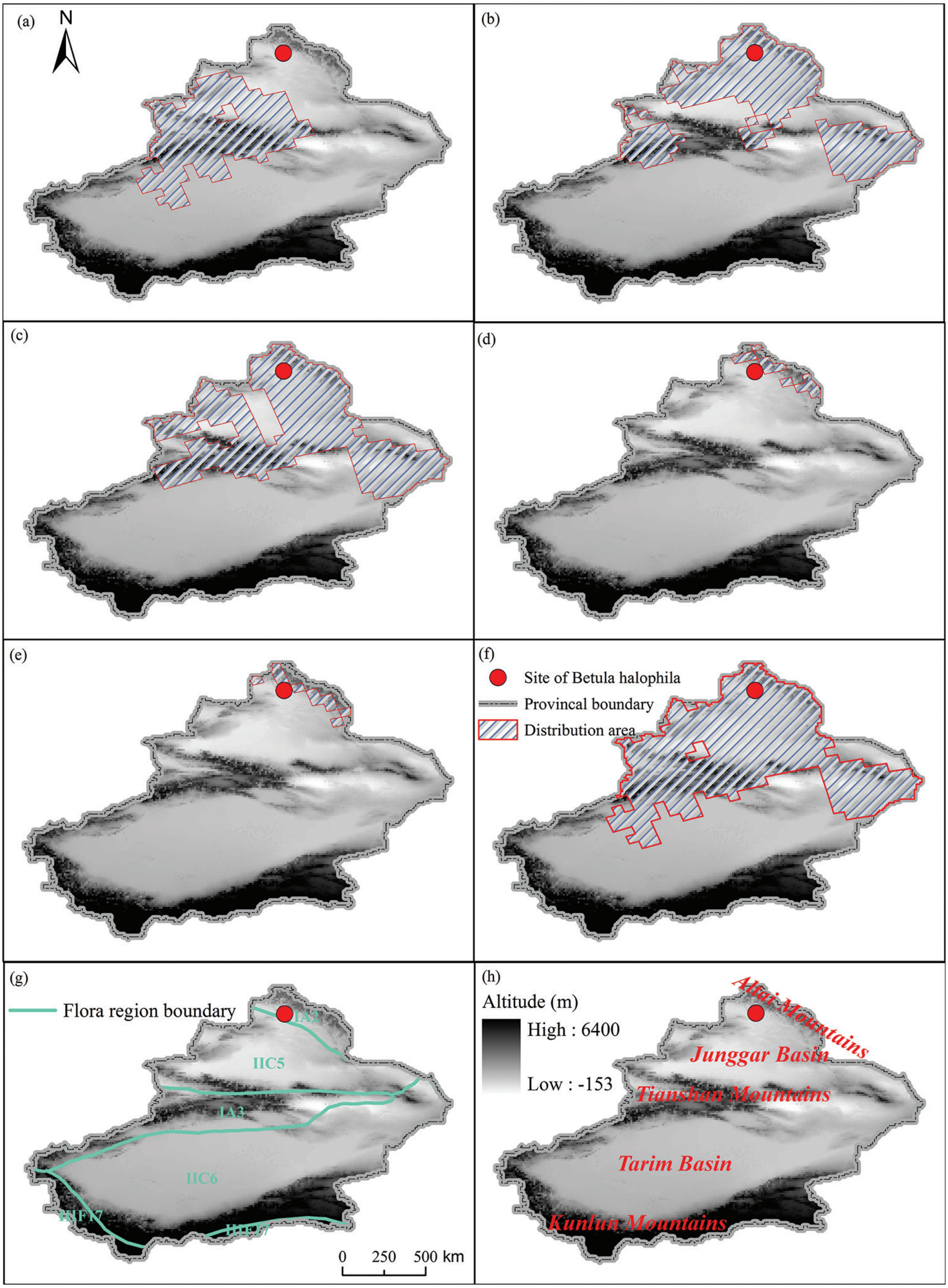

Figure 1. Geographic distribution of congeneric species with *Betula halophila*, flora regions and main geomorphology in Xinjiang, northwest China **a** geographic distribution of *B. tianschanica* **b** geographic distribution of *B. microphylla* **c** geographic distribution of *B. pendula* **d** geographic distribution of *B. rotundifolia* **e** geographic distribution of *B. humilis* **f** geographic distribution of five species of *Betula* genus in Xinjiang **g** geographic distribution of flora regions, IA2 Altai Region, IA3 Tianshan Region, IIC5 Junggar Region, IIC6 Kashgar Region, IIIF17 Tibet, Pamirs and Kunlun Region **h** geographic distribution of main geomorphology.

the main environmental and spatial factors were carried out by ANOVA and Scheffe multiple comparative analyses (Scheffe 1959) and by linear regression analysis, respectively. The above analysis are calculated, in turn, by *sørenson*, *aov*, *scheffe.test* and *lm* functions of *fossil*, *stats*, *agricola* and *vegan* packages in R software (R Core Team 2019). Spatial analysis tools are used to extract the corresponding environmental data values which include longitude, latitude, altitude, mean annual temperature, mean annual precipitation and mean annual evapotranspiration. Longitude and latitude are the longitude and latitude of the central coordinates of each 50 km × 50 km grid. Altitude, mean annual temperature, mean annual precipitation and mean annual evapotranspiration are average altitude, mean annual temperature, mean annual precipitation and mean annual evapotranspiration of each 50 km × 50 km grid, respectively. These four variables are obtained by extracting DEM, mean annual temperature, mean annual precipitation and mean annual evapotranspiration basic data layers of the study area in ArcGIS 9.3 (ESRI 2008). All spatial distribution maps are drawn in ArcGIS.

Results

Floristic composition across distribution areas of the five species congeneric with *B. halophila*

Across all the distribution areas of the five congeneric species of *B. halophila*, there are 3013 species of seed plants, belonging to 693 genera and 108 families. There are 33 species of gymnosperms and 2980 species of angiosperms. Amongst the 108 families, there are 368 species of Asteraceae, 283 species of Poaceae, 253 species of Fabaceae, 152 species of Rosaceae, 147 species of Ranunculaceae, 134 species of Lamiaceae, 128 species of Brassicaceae, 127 species of Chenopodiaceae, 114 species of Caryophyllaceae, 107 species of Apiaceae and 102 species of Liliaceae, all of which contain more than 100 species. Amongst the other families, 63 families contain less than 10 species. There are 22 families with only one species. Amongst the 693 genera, *Astragulus* has the most species, including 92 species, followed by *Carex* (60 species), *Allium* (56 species), *Artemisia* (53 species), *Oxytropis* (41 species), *Ranunculus* (41 species) and *Saussurea* (40 species). In addition, there is only one species in 307 genera.

There are 108 families of seed plants in the distribution area of congeneric species of *B. halophila*. The proportions of the cosmopolitan, temperate and tropical (Qian 2001) are 46.30%, 31.48% and 24.00%, respectively, which can be divided into eight types of geographical elements (Table 1). There are 693 genera of seed plants in the distribution area of the congeneric species of *B. halophila*. The proportions of the cosmopolitan, temperate and tropical are 10.39%, 79.80% and 9.81%, respectively, which can be classified into 15 types of geographical elements (Table 1). Amongst them, the proportions of the three types of geographical elements, Mediterranean region, West Asia and Central Asia, are the highest (Table 1).

The proportions of the cosmopolitan, temperate and tropical families are similar within all five species distribution areas and the proportion of the cosmopolitan fam-

Table 1. Statistics of geographic elements for families and genera in distribution areas for congeneric species with *Betula halophila* in Xinjiang, northwest China.

Geographic elements		Number	Percentage of	Number	Percentage of
Major types	Types	of families	total families (%)	of genera	total genera (%)
Cosmopolitan	Cosmopolitan	50	46.30	72	10.39
Tropical	Tropical Asia- Australia and Tropical America	21	19.44	42	6.06
	Tropical and Subtropical East Asia & (South) Tropical America disjuncted	3	2.78	5	0.72
	Old World Tropics	/	/	8	1.15
	Tropical Asia to Tropical Australia	/	/	4	0.58
	Tropical Asia to Tropical Africa	/	/	3	0.43
	Tropical Asia	/	/	6	0.87
Temperate	North Temperate	26	24.07	228	32.90
	East Asia & North America disjuncted	1	0.93	17	2.45
	Old World Temperate	4	3.70	120	17.32
	Temperate Asia	/	/	25	3.61
	Mediterranean, western Asia to central Asia	2	1.85	77	11.11
	Central Asia	1	0.93	62	8.95
	East Asia	/	/	15	2.16
	Endemic to China	/	/	9	1.30

Note: '/' indicates there is no corresponding geographical element type.

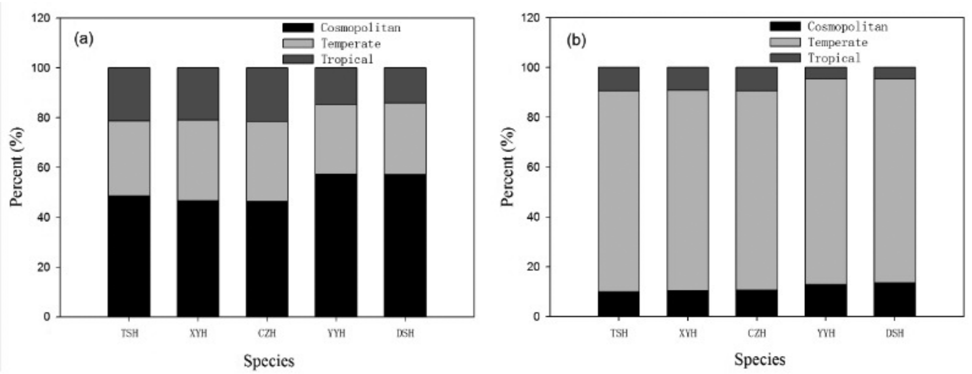

Figure 2. Percentage of geographic elements of compositions of different distribution areas for congeneric species with *Betula halophila* **a** family in different distribution areas for congeneric species with *B. halophila* **b** genus in different distribution areas for congeneric species with *B. halophila* (TSH: *B. tianschanica*; XYH: *B. microphylla*; CZH: *B. pendula*; YYH: *B. rotundifolia*; DSH: *B. humilis*) in Xinjiang, northwest China.

ily is dominant (Fig. 2a). The proportion of the cosmopolitan, temperate and tropical genera within all five species distribution areas are also similar, but the proportion of the temperate genus is absolutely dominant (Fig. 2b). The proportions of the cosmopolitan family and genus within species distribution areas of three shrub congeneric species of *B. halophila* are higher than those within species distribution areas of two tree congeneric species of *B. halophila* (Fig. 2a, b). It can be seen that the cosmopolitan families and temperate genera are dominant in the geographical components of seed flora in the distribution areas of congeneric species of *B. halophila* in Xinjiang.

Richness and similarity of plants amongst different species distribution areas of the five species congeneric with *B. halophila*

There was no significant difference in plant richness amongst the distributional areas of each of the five species congeneric with *B. halophila*, but there was a trend (Fig. 3a–c). The average family richness in distribution area of *B. tianschanica*, *B. microphylla*, *B. pendula*, *B. rotundifolia* and *B. humilis* are 49, 47, 48, 55 and 56, respectively. Family richness in all distribution areas of shrub species is higher than that in distribution areas of tree species (Fig. 3a). The average genus richness in distribution areas of the five species is 193, 197, 202, 235 and 250, respectively. The average genus richness in the distribution area of shrub species is higher than that in the distribution area of three tree species (Fig. 3b). The average species richness in the distribution area of the five species is 347, 358, 366, 473 and 520, respectively. The species richness in the distribution area of shrub species is higher than that in the distribution area of tree species, which is consistent with that of families and genera (Fig. 3c). The analysis of species similarity in different species distribution areas shows that the species composition in the distribution areas of *B. pendula* and *B. rotundifolia* is the most similar (Table 2) and that in the distribution areas of *B. pendula* and *B. microphylla* is the lowest (Table 2).

Changes of species richness with geographic and environmental factors

The species richness in the distribution areas of the five congeneric species of *B. halophila* varied not significantly with the increase in longitude ($R^2 = 0.00$, $P > 0.05$), but significantly increased with the increase in latitude ($R^2 = 0.27$, $P < 0.01$) (Fig. 4a, b). With the increase in altitude, the species richness also has no significant change (Fig. 4c). The species richness decreased with the increase in annual average temperature (Fig. 4d) and increased significantly with the increase in annual average precipitation and actual evapotranspiration (Fig. 4e, f). In all distribution areas of five species, there is a significantly negative correlation between altitude and mean annual temperature (Suppl. material 1: Fig. S1). However, the species richness in the distribution area of any species was not related to altitude (Table 3). In the distribution areas of different species, the species richness in areas of three tree species (*B. tianschanica*, *B. microphylla* and *B. pendula*) increased significantly with the increase of longitude, latitude, annual average temperature, annual precipitation and annual potential evapotranspiration

Table 2. Sørenson similarity coefficients of compositions in distribution areas of different species for congeneric species with *Betula halophila* in Xinjiang, northwest China.

	B. tianschanica	*B. microphylla*	*B. pendula*	*B. rotundifolia*	*B. humilis*
B. tianschanica	/	/	/	/	/
B. microphylla	1.04	/	/	/	/
B. pendula	1.06	1.02	/	/	/
B. rotundifolia	1.35	1.39	1.40	/	/
B. humilis	1.32	1.36	1.37	1.03	/

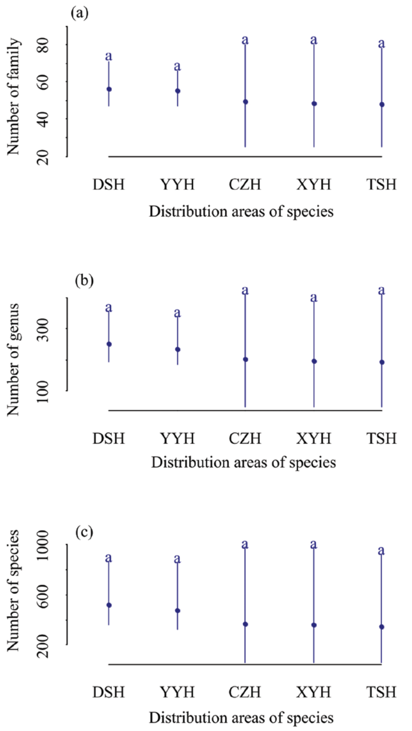

Figure 3. Comparisons of mean plant richness of different distribution areas for congeneric species of *Betula halophila* based on the spatial unit of 50 km × 50 km **a** number of families in different distribution areas for congeneric species with *B. halophila* **b** number of genera in different distribution areas for congeneric species with *B. halophila* **c** number of species in different distribution areas for congeneric species with *B. halophila*)(TSH: *B. tianschanica*; XYH: *B. microphylla*; CZH: *B. pendul*a; YYH: *B. rotundifolia*; DSH: *B. humilis*) in Xinjiang, northwest China.

Table 3. Correlations (R^2) between the species richness in species distribution areas of congeneric species with *Betula halophila* and their main environmental factors in Xinjiang, northwest China.

Species	Longitude	Latitude	Altitude	Mean annual temperature	Mean annual precipitation	Mean annual evapotranspiration
B. tianschanica	0.26*	0.23*	-0.01	0.03*	0.11*	0.14*
B. microphylla	0.11*	0.22*	-0.01	0.04*	0.14*	0.16*
B. pendula	0.07*	0.19*	-0.00	0.01*	0.09*	0.12*
B. rotundifolia	0.23*	0.01	0.07	0.00	-0.11	-0.11
B. humilis	-0.00	0.02	-0.08	-0.07	-0.08	-0.11

Note: The minus sign before the correlation coefficient denotes negative correlation and the * in the upper right corner denotes significant at P < 0.1.

(Table 3); the species richness in the distribution areas of *B. rotundifolia* increased only with the increase in longitude ($R^2 = 0.23$, $P < 0.1$). The temperature, precipitation and evapotranspiration of *Betula halophila* in the field were almost consistent with the most frequent occurrence of *Betula* species (Suppl. material 2: Fig. S2).

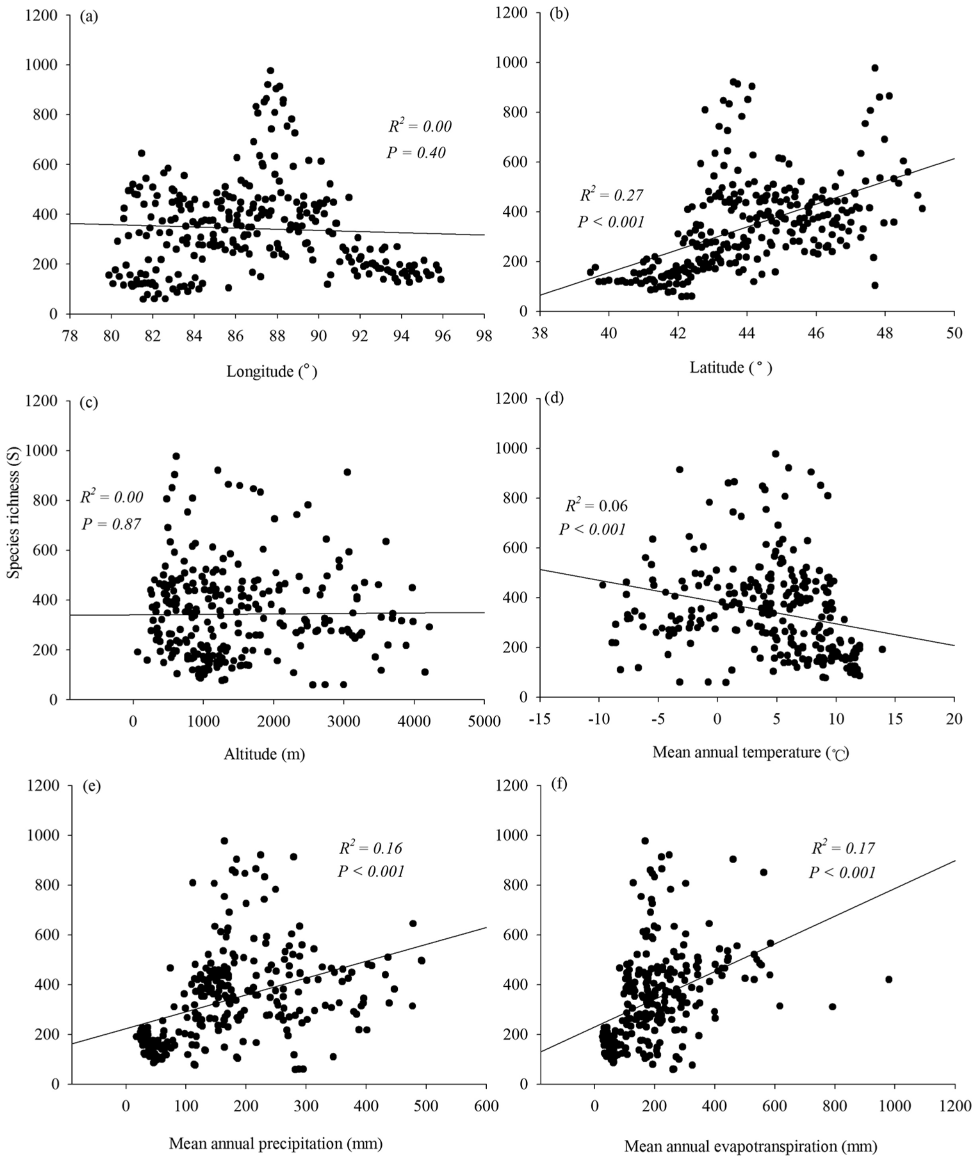

Figure 4. Relationships between species richness of distribution areas for congeneric species of *Betula halophila* and geographical and environmental factors in Xinjiang, northwest China.

Discussion

In the distribution area with *Betula* species, there are 3013 species, 693 genera and 108 families of seed plants, accounting for 86.16%, 94.54% and 93.91%, respectively, of the total seed plants in Xinjiang (Pan 1995). It can be seen that seed plant flora distributed in the distribution area of congeneric species of *B. halophila* is the majority of seed plant flora in Xinjiang. The seed plant flora is mainly composed of cosmopolitan and temperate distribution. The vegetation in the Altai area is gradually formed after the invasion of holarctic and ancient Mediterranean elements (Chen and Yang 2000). The Holarctic and the ancient Mediterranean elements are mainly cosmopolitan and temperate distribution. The main families of the seed plant flora, distributed in the distribution area of congeneric species of *B. halophila*, are Asteraceae, Poaceae, Fabaceae, Rosaceae, Ranunculaceae and Lamiaceae, all of which are cosmopolitan elements. Amongst of these families, the first three are super families of seed plants containing more than ten thousand species in the world (Wu and Wang 1983). Generally, the climatic conditions in the plant distribution areas, dominated by the cosmopolitan elements, are relatively harsh. Therefore, the seed plant flora, distributed in distribution areas of congeneric species of *B. halophila*, are mainly composed of the cosmopolitan plants, which, to a certain extent, indicate that congeneric species of *B. halophila* in Xinjiang have certain adaptability to the harsh climate (Pan 1995). In Xinjiang, there are a small number of tropical families or genera in the distribution area of congeneric species of *B. halophila*, which may be a legacy of flora under a hot climate in the early Tertiary in Xinjiang (Pan 1995). To some extent, it also reflects the uniqueness of the seed plant flora distributed in the distribution area of congeneric species of *B. halophila*, just like the uniqueness of seed plant flora in Xinjiang (Huang et al. 2011; Huang et al. 2018). Nearly 94% of the families of Xinjiang are found in the distribution area of congeneric species of *B. halophila*, which indicates the distribution areas of these species cover the diversity distribution centre of seed plants in Xinjiang. It seems to indicate that the seed plant flora, distributed in the distribution area of congeneric species of *B. halophila*, is of great importance, even equivalent to seed plant flora in Xinjiang. It can be seen that the distribution of the genus *Betula* is closely related to the distribution of seed plant diversity in Xinjiang.

According to the records of *Flora Xinjiangensis* (Editorial Committee of *Flora Xinjiangensis* 1992–2011), all species of congeneric species of *B. halophila* are mainly distributed in the Altai mountain area in Xinjiang, except for *B. tianschanica* which is mainly located in Tianshan Mountains. Amongst those four species mainly distributed in Altai, *B. pendula* and *B. microphylla* are also partly present in the western mountain areas of Junggar Basin. In Xinjiang, mountain coniferous forest is the main forest vegetation type, followed by mountain broad-leaved forest. The latter is closely related to the former. Amongst the mountain broad-leaved forests in Xinjiang, the small-leaved forest, composed of poplar and birch, is especially typical forest (Editorial Committee of Xinjiang Forestry 1989; Xinjiang Investigation Group of Chinese Academy of Sciences 1978). Some studies have shown that birch is an important component of Eurasian boreal coniferous forest (Taiga) which is cold resistant in the upper part of Altai Mountain (Chen and Yang 2000). In the Altai Mountains, birch-dominated broad-leaved forest (Chen and Yang 2000) widely occurs on many exposed hillsides, which reflects that birch forest is an important pioneer tree species in the vegetation development of the region (Chen 1999). Compared with other broad-leaved tree species, the small-leaved tree species is more resistant to severe cold and adapts to the northern mountains with a strong continental climate. The small-leaved tree species can be found almost in any areas distributed with coniferous forest. The small-leaved tree species is a light demander, not strict with soil, grows rapidly in young trees and provides strong competition to weeds. It is a typical pioneer tree species, creating a suitable environment for the regeneration and development of mountain coniferous forest of mountain forest in Xinjiang.

There are significant differences in plant richness amongst seed plant floras in the distribution area of congeneric species of *B. halophila*. The plant abundances of different life forms of these congeneric species are obviously different, while those of common life forms of these species are not significantly different. Latitude and climate have a significant influence on species richness in the distribution areas of congeneric species of *B. halophila*. It has been thought that latitude is actually a comprehensive factor. Therefore, we tend to think that climate is the key factor impacting on the distribution pattern of species diversity in the distribution areas of congeneric species of *B. halophila*, which also conforms to the view that climate plays a key role in species diversity in Xinjiang (Li et al. 2013). The species richness in the distribution areas of all tree congeneric species of *B. halophila* are influenced by climate factors, while the species richness in the distribution areas of all shrub congeneric species of *B. halophila* are not. There is no significant change of species richness with altitude, which may further indicate that there is a regional difference in patterns of species richness with altitude gradients in the distribution areas of all shrub congeneric species of *B. halophila* (Li et al. 2011).

Wild populations of *B. halophila* have not been found in the field since 2003. The biological characteristics of the species need to be further understood in order to realise its effective protection and return in the wild. Due to the lack of wild population, the understanding of its ecological characteristics is very limited. Our study will help to strengthen the understanding of this species through the analysis of species composition, floristic characteristics and species diversity of the native congeneric of this species. From the point of view of phylogeny, it is necessary to carry out an in-depth study combined with the phylogeny of this species. From the current research, the phylogenetic relationship between this species and other related species is not clear. The clear phylogenetic relationship of this species is helpful to reveal the origin of this species and provide an important traceability basis for its protection. In terms of floristic composition, the cosmopolitan families and temperate genera are dominant in the distribution area of *B. halophila*. The climate niche of the species in the wild is consistent with that of *Betula* genus. It seems that niche simulation can be used to simulate the potentially suitable distribution area of *B. halophila*, which provides an important basis for the selection of the wild return to a great extent. Therefore, the current optimum distribution area of *Betula* genus in Xinjiang is the preferred geographical region for wild return of *B. halophila* when the primary wild habitat of *B. halophila* is not suitable for its survival at local scale any more. From this study, we also found that there are obvious differences in the factors affecting the species distribution at the local scale and in different distribution areas of related species. Therefore, more factors should be considered in the follow-up and the community level investigation work should be carried out in order to provide an important ecological reference for the wild return of *B. halophila*.

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Supplementary material 1

Figure S1. The correlation between environmental variables in distribution areas of five congeneric species with *Betula halophila*

Authors: Jihong Huang, Zhongjun Guo, Suying Tang, Wei Ren, Guangming Chu, Liping Wang, Ling Zhao, Ruoyun Yu, Yue Xu, Yi Ding, Runguo Zang

Data type: Generating graph based on measurement and occurrence data.

Explanation note: The correlation between longitude (Long), latitude (Lati), altitude (Alti), mean annual temperature (Tem), mean annual precipitation (Pre) and evapotranspiration (Et) in distribution areas of five congeneric species with *Betula halophila*. (a) TSH: *B. tianschanica*; (b) XYH: *B. microphylla*; (c) CZH: *B. pendula*; (d) YYH: *B. rotundifolia*; (e) DSH: *B. humilis*).

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Supplementary material 2

Figure S2. The distribution frequency of *Betula* species varies with the environment gradients

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Data type: Generating graph based on measurement and occurrence data.

Explanation note: The distribution frequency of *Betula* species varies with the environment gradients and the environmental variable values of *Betula halophila* were once distributed in the field.

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