Nature Conservation 48: 83–93 (2022)
doi: 10.3897/natureconservation.48.79902
https://natureconservation.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

A rare shrub species as flagship for conserving desert steppe in arid Inner Mongolia

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Academic editor: M. Nazre | Received 29 December 2021 | Accepted 12 April 2022 | Published 20 April 2022

http://zoobank.org/3BD079FB-FEB6-4943-9E03-043F13D38B8D

Citation: Yang H, Xu C, Chu J, Chen J, Gan H, Zhou Z (2022) A rare shrub species as flagship for conserving desert steppe in arid Inner Mongolia. Nature Conservation 48: 83–93. https://doi.org/10.3897/natureconservation.48.79902

Abstract

The rare species *Amygdalus pedunculata* Pall. (Rosaceae) in arid northern China is endangered to the point of extinction. Determined to save it, the local government of Inner Mongolia Autonomous Region encouraged the herdsmen to limit grazing activities. Here, we are testing if this species could be considered as a conspicuous flagship for restoring and conserving wind-sensitive arid lands as desert steppe in northern China. We examined statistically the growing states and environmental roles of *A. pedunculata* populations under the comparative conditions of free and limited grazing in winter since the year 2001. This species was observed to play a critical role in preventing wind erosion and stabilising the lands, as was indicated by the formation of micro-dunes under the shrubs. This role can be attributed mainly to the crown diameters or cover from the shrubs. Under the grazing limitation condition, accompanying species and plants around the shrubs increased significantly. Regardless of free or limited grazing conditions, the shrubs were not observed to inhibit the occurrence or growth of other plants. The grazing limitation over a period of 20 years has caused the effective revival of the rare *A. pedunculata* species, with statistically larger and taller *A. pedunculata* individuals than under the free grazing condition, as well as a slightly higher population density and total crown cover. The grazing limitation policy for saving *A. pedunculata* is believed to be effective and the rare *A. pedunculata* shrub is a conspicuous flagship for helping to conserve wind-sensitive desert steppe in terms of ecosystem integrity and authenticity.

* These authors contributed equally to this work.

Keywords
Amygdalus pedunculata Pall. (柄扁桃), desert steppe, ecosystem conservation, flagship species, sand stabilisation, wind erosion

Introduction

Aeolian erosion is a key factor against arid lands, such as desert steppe in northern China (Wang 2014; Wijitkosum 2021; Wu et al. 2021). Plants in desert steppe are normally reduced in size and density; once these plants are damaged, winds can cause intense soil erosion (Meng et al. 2018). Inhabitants basically live by grazing sheep, cattle, horses and camels from time immemorial (Du et al. 2019). Vegetation degradation has occurred in these areas because of overgrazing in the past; subsequent wind erosion then led to land degradation and severe dust storms (Liu et al. 2009; Liu et al. 2017; Du et al. 2019). Dusts spread extensively to pollute the atmosphere on a vast scale (Tian et al. 2021). On the other aspect, a number of native species are becoming extinct with the degradation (Liu et al. 2015; Yang et al. 2017). These emerging crises are detrimental not only to the sustainable livelihood of the local population, but also to public interests in national and even international levels for resource availability (Gholizadeh et al. 2021; Luo et al. 2022). Any rare species with unique genetic resources may potentially benefit all human beings, other than just local people within a limited area (Cardinale et al. 2012; O'Brien et al. 2021).

Amygdalus pedunculata Pall. [柄扁桃, used to be named *Prunus pedunculata* Pall.] is a rare shrub species naturally endemic to the desert steppe in northern China; it produces beautiful flowers in early spring and delicious oily seeds in autumn (Chu et al. 2015, 2017; Gao et al. 2016). However, this species has suffered from overgrazing with undue livestock herbivory and trampling for many years and most of the local populations have disappeared, except at few sites. Considering the rarity and endangered status of this species, the local government of Inner Mongolia Autonomous Region, in 1989, introduced a policy to save it (Government-Bulletin 1989). This species may be a conspicuous flagship for restoring and conserving the desert steppe as land- and biotic-resources (Herrera-Sanchez et al. 2020; Lachowska-Cierlik et al. 2020; Shen et al. 2020). From 2001, some herdsmen whose pastures contain remnant *A. pedunculata* populations are officially encouraged to limit their grazing activities, thereby ensuring that these remnant populations will renew or revive. According to a special policy, the government will provide the participating herdsmen with necessary financial compensation if they agree to cease grazing in lands where *A. pedunculata* grows, except in winter when forage is extremely short.

Even so, no herdsmen were willing to have all their lands used as this policy required because they must live by graze. Thus, only a part of remnant *A. pedunculata* populations are conserved as regulated by the policy, and other parts are still suffering from free grazing. After nearly 20 years, we herein investigated the growing status of *A. pedunculata* populations under the comparative conditions of

free and limited grazing. We tested whether the current conservation policy is effective for saving and restoring this rare species and whether this species is a useful conspicuous flagship for restoring and maintaining the desert steppe as a whole of land- and biotic-resources.

Methods

Sampling and measuring

This study was conducted at a natural distribution site of *A. pedunculata* (42°34'33.93"N, 112°30'58.74"E, Fig. 1a). Elevations range from 900 m to 1260 m. The soil is brown calcic, covered with thin sand. The underground water is more than 20 m below the surface. The mean annual precipitation is about 190 mm and the mean annual evaporation is about 2400 mm. The rainy season is June, July and August, accounting for nearly 70% of the annual precipitation (Shen and Wei 2008). Strong winds (> 17.2 m/s) occur in ca. 60 d each year, and sand storms occur in more than 12 days each year. Natural vegetation is sparse desert steppe (Fig. 1b). Overgrazing in this area was very common before 2000, thus causing vegetation and land degradation (Zhang et al. 2021a; Zhang et al. 2021b). Since 2001, some involved herdsmen have been financed to graze only in winter in some pastures where *A. pedunculata* occurs; even so, many *A. pedunculata* populations are out of the protection.

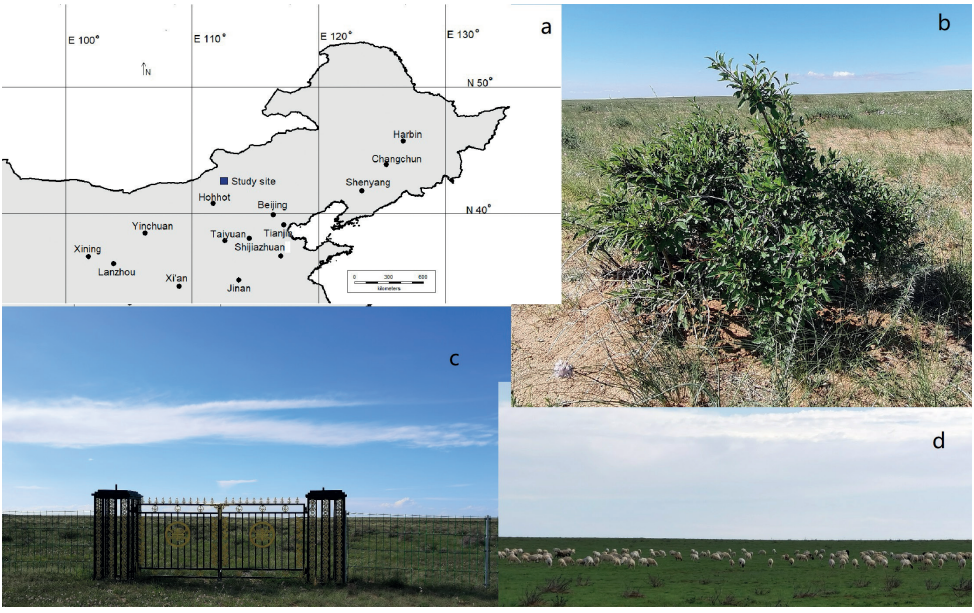

Figure 1. Study site (**a**) and *A. pedunculata* (**b**) in arid desert steppe in northern China. Two scenes were compared: limited grazing (**c**) to only winter and free grazing (**d**) throughout the year. Taken by Hongxiao Yang.

We chose two typical scenes for the study: one is fenced since 2001 and only for winter grazing (Fig. 1c) and the other is open and used for free grazing throughout the year (Fig. 1d). In each scenario, we randomly chose 27 individuals of *A. pedunculata* shrubs. For each shrub, we measured the relative height (cm) from the top to the foot of the micro-dune under the shrub and the crown diameter (cm), which is the mean of the longest and shortest diameters of each shrub crown. We counted the number of branches that emerged from the ground. We also investigated accompanying plants around the shrub with three 1 m parallels at three distance (position) levels (a, just inside the crown projection; b, at the edge of the crown projection; c, 1 m away from the crown projection); this investigation was repeated four times in different directions. In these sampling lines, we counted the number of occurring species and the total number of growing plants. We then established 15 random 10 × 10 m plots in each scene, where we counted all *A. pedunculata* shrubs and measured their heights (cm) and crow diameters (cm) as above.

Data analysis

We calculated Pearson coefficients of the dune height with height, branch number and mean crown diameter of the corresponding shrub to determine which feature is critical for the effect of sand stabilisation. We also established a linear model for demonstrating the relationship. Using two-way ANOVA, we examined the effects of the two grazing modes and the distances away from the shrubs on the numbers of occurring species and plants. We conducted a T-test for comparing the growth states of *A. pedunculata* populations in the two grazing modes by using four indices, namely, population density (shrub number in a 10 × 10 m plot), total crown area (total *A. pedunculata* crown area in a 10 × 10 m plot) and maximum height and crown diameter of *A. pedunculata* individuals in each plot. The total *A. pedunculata* crown area was set as the total crown area of all *A. pedunculata* individuals in a plot and crown area (cover) of an *A. pedunculata* individual was calculated with the formula: $\pi \times (\text{diameter}/2)^2$. All these analyses were completed in R4.1.1 software (www.r-project.org).

Results

The sand stabilisation effect of the shrubs can be attributed mainly to the crown diameters of the shrubs and can be fitted with a linear model (Table 1, Fig. 2). Branch number also contributed to this effect under the condition of free grazing, but had less contribution under the condition of limited grazing.

Table 1. Correlation of dune height with shrub features under the two grazing conditions.

Grazing mode	Crown diameter	Branch number	Shrub height
Free grazing	0.614***	0.508**	0.307
Limited grazing	0.549**	0.280	0.086

*, $r_{(1, 25)0.05} = 0.381$; **, $r_{(1, 25)0.01} = 0.487$; **, $r_{(1, 25)0.001} = 0.597$

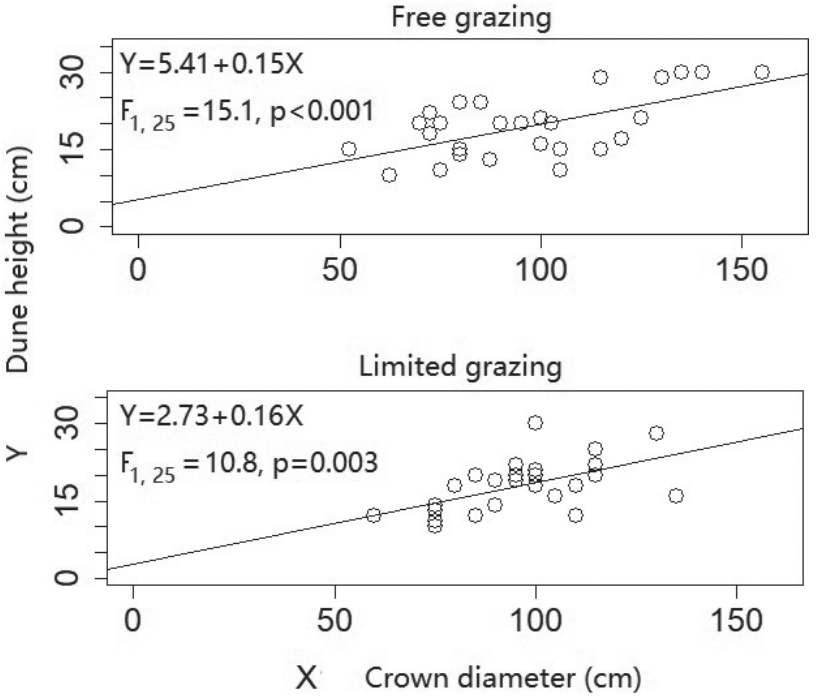

Figure 2. Relationship of height of shrub-caused micro-dune with crown diameter of the pertaining *A. pedunculata* shrub. The upper part is under the condition of free grazing and the lower part is under the condition of limited grazing.

Species and plant numbers were affected by the grazing modes, instead of the shrubs (Fig.s 3, 4). The two-way ANOVA indicated that both plant and species numbers under or near the shrubs were sensitive to the grazing modes, other than the shrubs and their interactive effect with the grazing modes (Plants: grazing modes, $F_{(1, 114)} = 61.73$, $p < 0.001$; distances to the shrubs, $F_{(2, 114)} = 7.1$, $p = 0.47$; interactive effect of the grazing and the distances, $F_{(2,114)} = 4.1$, $p = 0.65$. Species: grazing modes, $F_{(1, 114)} = 78.41$, $p < 0.001$; distances to the shrubs, $F_{(2, 114)} = 3.02$, $p = 0.29$; interactive effect of the grazing and the distances, $F_{(2,114)} = 5.82$, $p = 0.10$). Averages of plant numbers in the sampling unit were < 5 in the free grazing condition, and > 5 in the limited grazing condition (Fig. 3); averages of species numbers were ca. 3 in the free grazing condition, and evidently > 3 in the limited grazing condition (Fig. 4).

The grazing limitation evoked positive changes in *A. pedunculata* populations (Fig. 5). Under the condition of limited grazing, large-crowned *A. pedunculata* shrubs were observed to be more common than those under the condition of free grazing (T-test, $t = 2.62$, $df = 24.717$, $p = 0.015$). Similarly, tall *A. pedunculata* shrubs were significantly more common than those under the condition of free grazing (T-test, $t = 3.40$, $df = 26.11$, $p = 0.002$). The population density and total crown area also increased but not to such a significant extent (Density: T-test, $t = 1.20$, $df = 25.44$, $p = 0.241$. Total crown area: T-test, $t = 1.55$, $df = 25.857$, $p = 0.135$).

Figure 3. Numbers of plants occurring in different distances to the nearest *A. pedunculata* shrub. The upper part is under the condition of free grazing and the lower part is under the condition of limited grazing.

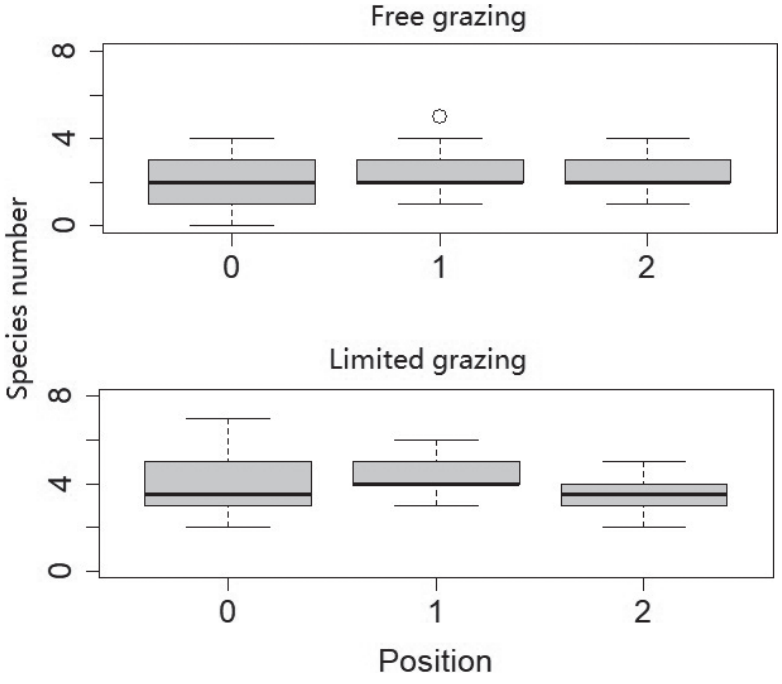

Figure 4. Numbers of species occurring in different distances to the nearest *A. pedunculata* shrub. The upper part is under the condition of free grazing and the lower part is under the condition of limited grazing.

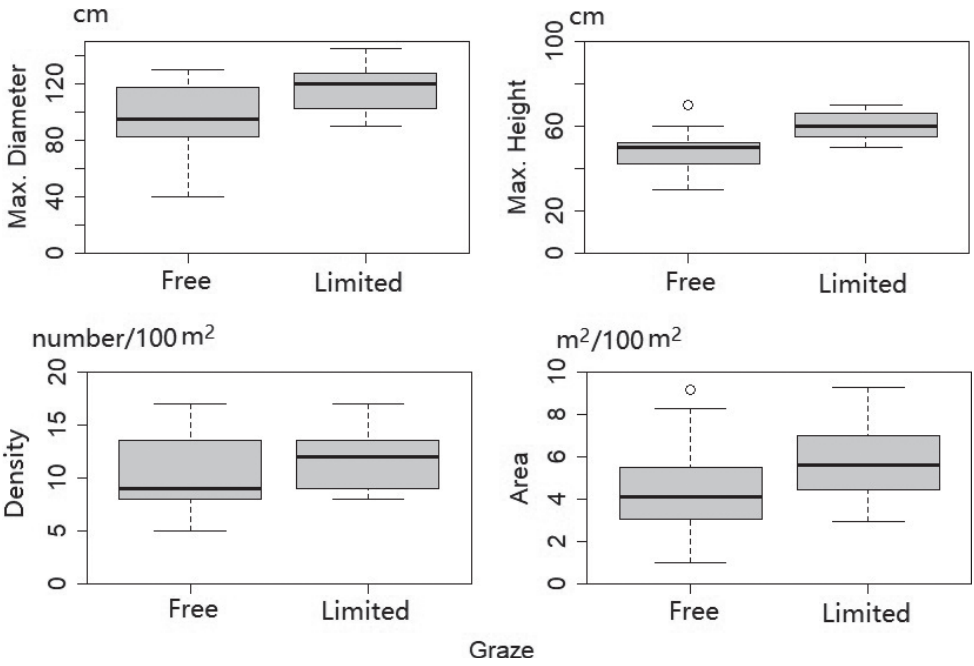

Figure 5. Changes in *A. pedunculata* populations in response to the two grazing modes: the upper part, free grazing; the lower part, limited grazing. The compared indices include maximum crown diameter and height of *A. pedunculata* shrubs in a sampled 10 × 10 m plot, as well as density and total crown area of all *A. pedunculata* shrubs in each plot.

Discussion

Amygdalus pedunculata populations and accompanying plants grew much better under the condition of limited grazing than under the condition of free grazing, presumably because of weakened herbivory and animal trampling. One significant change is that large and tall *A. pedunculata* individuals became more common under the condition of limited grazing. Another significant change is that the number of accompanying plants and species was definitely higher than that under the condition of free grazing. Other changes, such as population density and total crown area of *A. pedunculata* populations, were not so significant, but certainly not lower than those under the condition of free grazing. This evidence demonstrates that the policy of grazing limitation is effective to facilitate the thriving of *A. pedunculata* and accompanying plants. In contrast, free grazing with heavy herbivory and trampling prevented *A. pedunculata* and accompanying plants from renewing and thriving.

Most arid deserts are sensitive to wind erosion (Chi et al. 2019; Fenta et al. 2020). Once they are deprived of vegetation cover for long-term overgrazing, they will seriously suffer from erosive winds or storms so as to output flying dust and rolling sand (Zhang et al. 2021c). Under the condition of free grazing, we found that sand was deposited under *A. pedunculata* crowns, piling as micro-dunes, and accompanying plants were too scarce to protect the land from potential wind erosion. As thus, we state that it is *A. pedunculata* shrubs, instead of accompanying plants, that mainly stop sand drift and protect the lands

(Zhan et al. 2017). This finding may be due to the fact that soft herbs or grasses, as main forage, are often the prior victim in grazing events, whereas woody shrubs as *A. pedunculata*, except their seedlings, can avoid this relatively better for lessened herbivory and trampling (Fan et al. 2016; Zhang et al. 2019; Sun et al. 2020). In addition, the crown diameter of the *A. pedunculata* shrub was observed to be closely correlated with the height of the under-crown fine sand dune, which shows the effect of sand stabilisation.

The rare *A. pedunculata* is urgently endangered. However, involved herdsmen must live by grazing stocks, and they especially concern forage production, i.e., grass growth, other than *A. pedunculata*. This study shows that *A. pedunculata* shrubs do not inhibit accompanying plants for growing, no matter whether under the condition of free grazing or under the condition of limited grazing. For this reason, herdsmen or land owners can be assured that *A. pedunculata* is almost harmless to forage production, and that, after *A. pedunculata* populations are re-established, the lands can be protected better than without the shrubs from potential wind erosion and land degradation. What is more, they can harvest some *A. pedunculata* seeds to be sold in the market as raw materials for horticultural breeding or oil production (Li et al. 2010; Chu et al. 2015; Wang et al. 2020). Thus, monetary values of this species can be realised partly in serving more people.

Conclusions

The rare species *A. pedunculata* is worth conserving, because it can protect lands from wind erosion, while does not inhibit the growth of accompanying plants. The current policy for saving *A. pedunculata* is effective. With the grazing limitation over a period of 20 years, *A. pedunculata* resources have been renewed effectively and the pertaining lands have been restored with more plants and species. The shrub species *A. pedunculata* can be viewed as a conspicuous flagship for comprehensively restoring and conserving the natural desert steppe in northern China in terms of ecosystem integrity and authenticity, that is, all ecosystem components including native plants, animals and their desired habitat can be conserved as a whole because of the in-situ conservation for *A. pedunculata*.

Acknowledgements

We gratefully acknowledge HE Dongxiao in Qingdao Agricultural University. Funding: This study is funded by Fundamental Research Funds of CAF (CAFYBB2020ZB001), Special Foundation for National Science and Technology Basic Research Program of China (2017FY100205) and Qingdao Agricultural University.

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