Postprint: Diversity and Distribution Patterns of Gobi Shrub Communities in the Western Hexi Corridor

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Abstract

Through field quadrat surveys, this study investigated the diversity status of typical shrub communities in the desert Gobi of the western Hexi Corridor, examining the spatial distribution patterns of species diversity in eight typical shrub communities and their relationships with geographic factors, which holds significant importance for the conservation and sustainable development of plant community diversity in desert Gobi ecosystems. The results indicated: (1) The Shannon-Wiener index, Simpson index, Margalef index, and Pielou index of the eight typical shrub communities, in descending order, were: Kalidium community > Ephedra community > Sympegma community > Reaumuria community > Haloxylon community > Nitraria community > Tamarix community > Calligonum community; with ranges of 0.314–1.355, 0.179–0.666, 0.334–1.222, and 0.051–0.218, respectively, indicating that species diversity indices of desert Gobi shrub communities were relatively low, with simple community structure and sparse species composition. (2) The greater the number of species within different shrub communities, the larger the Jaccard similarity coefficient between communities. Jaccard similarity between most shrub community types ranged from 0.20 to 0.60, demonstrating low similarity levels and relatively stable communities. (3) With increasing altitude, the Margalef index, Pielou index, and Shannon-Wiener index all exhibited a unimodal distribution pattern of initially increasing then decreasing, with maximum values occurring at 2,000 m elevation, and were significantly correlated with altitude ($P<0.05$); along the longitudinal gradient, from east to west, the Margalef index, Pielou index, and Shannon-Wiener index showed an increasing pattern, but were not significantly correlated with longitude ($P>0.05$); along the latitudinal gradient, from south to north, the Margalef index, Pielou index, and Shannon-Wiener index showed a significant increasing trend ($P<0.05$). Overall, species diversity of desert Gobi shrub communities exhibited distinct vertical (altitudinal) and latitudinal zonation distribution patterns.

Gobi Shrub Species Diversity and Its Distribution Pattern in the Western Hexi Corridor

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Abstract

Through field quadrat surveys of typical shrub communities in the desert gobi region of the western Hexi Corridor, this study investigated the spatial distribution patterns of shrub community species diversity and their relationships with geographical factors. The findings are significant for the conservation and sustainable development of plant diversity in desert gobi ecosystems. The results showed that: (1) Among eight typical shrub communities, the Shannon-Wiener index, Simpson index, Margalef index, and Pielou index ranked from highest to lowest as follows: *Kalidium foliatum* community > *Sympegma regelii* community > *Ephedra przewalskii* community > *Nitraria sphaerocarpa* community > *Tamarix ramosissima* community > *Reaumuria songarica* community > *Haloxylon ammodendron* community > *Calligonum mongolicum* community. The fluctuation ranges were 0.334-1.355, 0.179-0.666, 0.051-0.218, and 0.314-1.355, respectively, indicating low species diversity indices, simple community structure, and sparse species composition in desert gobi shrub communities. (2) The more species within a community, the higher the Jaccard similarity coefficient between communities. Most similarity coefficients among shrub community types ranged from 0.20 to 0.60, indicating low similarity levels and relatively stable communities. (3) With increasing altitude, most Margalef and Pielou indices showed a unimodal distribution pattern of first increasing then decreasing, with maximum values appearing around 2,000 m, and these were significantly correlated with altitude ($P < 0.05$). Along the longitude gradient from east to west, the Shannon-Wiener index showed an increasing pattern but was not significantly correlated with longitude ($P > 0.05$). Along the latitude gradient from south to north, the Shannon-Wiener index showed a significant increasing trend ($P < 0.05$). Overall, shrub community species diversity in the desert

gobi exhibited distinct vertical (altitudinal) and latitudinal zonal distribution patterns.

Keywords: desert gobi; shrub communities; species diversity; geographical distribution

1.1 Study Area Overview

The study area is located at the western end of the Hexi Corridor, spanning Dunhuang City, Jinta County, Guazhou County, Subei County, and Aksai County in Gansu Province. The region is bounded by the Altun Mountains, Qilian Mountains, Mazong Mountains, and Beishan Mountains, with terrain that slopes from high in the south to low in the north, creating substantial altitudinal gradients ranging from 800 to 3,200 m. Geographically, the area extends from 92°09 to 100°20 E and 37°58 to 42°48 N. The climate is mid-temperate arid, with extremely uneven precipitation distribution decreasing from south to north. Annual precipitation reaches a maximum of 300 mm in the Qilian Mountains and a minimum of approximately 39 mm in the northern Mazong Mountains. Evaporation ranges from 2,000 to 4,000 mm, temperature varies 4-10 °C annually, solar radiation is intense, and total annual sunshine exceeds 3,000–4,000 hours. The region exhibits typical desert gobi climate characteristics: scarce precipitation, long sunshine hours, strong winds, cold winters, and hot summers. Brown desert soil is the dominant soil type.

1.2.1 Plot Setup and Survey

Field monitoring was conducted in multiple surveys along transects. Vegetation quadrats were established using GPS, with each plot' s longitude, latitude, and altitude recorded (Table 1). All plant species within each quadrat were recorded, and their height, crown width, and individual numbers were measured. Shrub quadrats measured 10 m × 10 m, while herb quadrats measured 1 m × 1 m. Additional plots were established whenever vegetation types changed, totaling 110 shrub quadrats and 440 herb quadrats (Figure 1). Community coverage was obtained through UAV imagery, using Pix4D software to stitch images and calculate total community coverage.

[Figure 1: see original paper]

1.2.2 Calculation Formulas

The following diversity indices were calculated:

- **Margalef richness index:** $D = (S-1)/\ln N$
- **Pielou evenness index:** $J = -\sum_{i=1}^{S}(P_i \ln P_i)/\ln S$
- **Shannon-Wiener diversity index:** $H' = -\sum_{i=1}^{S} P_i \ln P_i$
- **Simpson diversity index:** $D = 1 - \sum_{i=1}^{S} P_i^2$

- **Jaccard similarity coefficient:** $C_j = c/(a + b - c)$
- **β diversity index:** $\beta_c = (a + b - 2c)/(a + b)/2$

Where S is the total number of species in the quadrat, N is the total number of individuals, P_i is the proportion of individuals of species i, and a, b are species numbers in different quadrats while c is the number of shared species.

1.2.3 Data Analysis

Using Excel 2003, scatter plots were created and trend lines (linear, logarithmic, power, exponential, polynomial) were fitted. The trend line with the highest R^2 value was selected to explore diversity index variation along altitudinal, longitudinal, and latitudinal gradients. Grid meteorological data were obtained from the National Meteorological Information Center, and quadratic interpolation was used to calculate mean annual precipitation and temperature for each plot. Correlation analysis examined relationships between shrub community coverage, diversity indices, and meteorological factors.

2.1 Species Composition of Gobi Shrub Communities

The survey identified 29 shrub (semi-shrub) species belonging to 12 families and 19 genera, with Chenopodiaceae and Asteraceae as dominant families (48.28% of total species). Eight shrub community types were classified based on importance values: *Sympegma regelii* community, *Reaumuria songarica* community, *Ephedra przewalskii* community, *Nitraria sphaerocarpa* community, *Kalidium foliatum* community, *Calligonum mongolicum* community, *Haloxylon ammodendron* community, and *Tamarix ramosissima* community. Average species numbers per community type were 8, 9, 9, 8, 13, 5, 6, and 7, respectively.

Secondary dominant species varied among communities: *Sympegma regelii* communities were codominated by *Reaumuria songarica* and *Nitraria sphaerocarpa*; *Reaumuria songarica* communities by *Nitraria sphaerocarpa* and *Sympegma regelii*; *Ephedra przewalskii* communities by *Sympegma regelii* and *Reaumuria songarica*; *Nitraria sphaerocarpa* communities by *Reaumuria songarica* and *Sympegma regelii*; *Kalidium foliatum* communities by *Reaumuria songarica* and *Sympegma regelii*; *Calligonum mongolicum* communities by *Ephedra przewalskii* and *Sarcozygium xanthoxylon*; *Haloxylon ammodendron* communities by *Nitraria sphaerocarpa* and *Calligonum mongolicum*; and *Tamarix ramosissima* communities by *Alhagi sparsifolia* and *Nitraria sphaerocarpa*. Species dominance was pronounced, with *Reaumuria songarica*, *Sympegma regelii*, and *Nitraria sphaerocarpa* occurring frequently and having high importance values across communities.

2.2 Alpha Diversity of Shrub Communities

Diversity indices varied significantly among shrub communities ($P < 0.05$). The Margalef, Pielou, and Shannon-Wiener indices were highest in *Kalidium foliatum* communities and lowest in *Calligonum mongolicum* communities, with ranges of 0.334–1.222, 0.179–0.666, and 0.051–0.218, respectively. Overall, desert gobi shrub communities exhibited low species diversity, simple structure, and extremely uneven species distribution. However, strong environmental heterogeneity created significant differences in diversity levels: *Tamarix ramosissima* communities, distributed only along riverbanks, showed poor stability due to water availability fluctuations, whereas *Sympegma regelii* and *Ephedra przewalskii* communities, adapted to wind and drought, were widely distributed and more stable. *Kalidium foliatum*, a salt-meadow species, benefited from snowmelt and formed stable salt crusts, resulting in higher diversity. ANOVA revealed that *Kalidium foliatum*, *Ephedra przewalskii*, and *Sympegma regelii* communities had significantly higher Shannon-Wiener and Margalef indices, while *Reaumuria songarica*, *Haloxylon ammodendron*, and *Nitraria sphaerocarpa* communities showed significantly lower values ($P < 0.05$). *Tamarix ramosissima* and *Calligonum mongolicum* communities had significantly lower Pielou indices than other types ($P < 0.05$).

[Figure 2: see original paper]

2.3 Beta Diversity of Shrub Communities

Most Jaccard similarity coefficients among shrub communities ranged from 0.20 to 0.60, indicating low similarity and relatively stable communities. Some differences existed: *Tamarix ramosissima* communities showed the lowest similarity with *Sympegma regelii* and *Kalidium foliatum* communities (0.09–0.11), while *Sympegma regelii* and *Kalidium foliatum* communities shared the highest similarity (0.58). *Tamarix ramosissima*, *Haloxylon ammodendron*, and *Calligonum mongolicum* communities had similarity coefficients below 0.25 with other communities. Beta diversity trends were inverse to Jaccard similarity: higher species richness within communities corresponded to greater similarity coefficients and lower beta diversity. *Sympegma regelii*, *Reaumuria songarica*, *Ephedra przewalskii*, *Nitraria sphaerocarpa*, and *Kalidium foliatum* communities showed high similarity (>0.50) and wide niche breadth, indicating broad distribution and strong adaptability in the gobi region.

2.4 Altitudinal, Longitudinal, and Latitudinal Patterns of Community Coverage and Diversity

Vegetation coverage and diversity indices (Margalef, Pielou, Shannon-Wiener) showed unimodal patterns along the altitudinal gradient, first increasing then decreasing, with maxima at approximately 2,000 m (Figure 3). Polynomial regression revealed significant correlations ($P < 0.05$), with diversity indices showing convex curves and coverage showing a concave curve, demonstrating a "mid-altitude bulge" pattern. Along the longitudinal gradient, vegetation coverage, Margalef, and Pielou indices increased from east to west, with polynomial and linear trends being nearly identical. Only vegetation coverage showed significant correlation with longitude ($P < 0.05$), while diversity indices did not ($P > 0.05$). Along the latitudinal gradient, vegetation coverage, Margalef, Pielou, and Shannon-Wiener indices increased from south to north. Polynomial and linear trends were nearly identical, with Pielou and Shannon-Wiener indices showing highly significant positive correlations ($P < 0.01$) and Margalef index showing significant correlation ($P < 0.05$).

[Figure 3: see original paper]

2.5 Relationships Between Community Coverage, Diversity, and Meteorological Factors

Correlation analysis revealed that species diversity indices were positively correlated with precipitation and negatively correlated with temperature, but not significantly ($P > 0.05$). Only community vegetation coverage showed significant responses to meteorological factors: highly significantly positively correlated with precipitation ($P < 0.01$) and highly significantly negatively correlated with temperature ($P < 0.01$).

3.1 Characteristics of Gobi Shrub Community Species Diversity

The western Hexi Corridor slopes from southwest to northeast, with high altitudes at low latitudes and low altitudes at high latitudes, creating substantial topographic variation. Altitude significantly influences spatial distribution and species diversity patterns, with clear latitudinal zonation. Species diversity objectively reflects species richness and distribution uniformity. Gobi shrub community diversity indices are lower than those in typical desert regions, reflecting sparse vegetation, simple community structure, and uneven species distribution. However, low diversity does not necessarily indicate poor ecosystem stability, as populations are dominated by shrubs and semi-shrubs that maintain diversity through intensive clonal reproduction.

The ranking of diversity indices was: *Kalidium foliatum* > *Sympegma regelii* > *Ephedra przewalskii* > *Nitraria sphaerocarpa* > *Tamarix ramosissima* > *Reaumuria songarica* > *Haloxylon ammodendron* > *Calligonum mongolicum* communities. Higher species richness within communities corresponded to higher Jaccard similarity coefficients. Based on similarity coefficients, community pairs were classified as: extremely similar (0.75-1.00), moderately similar (0.50-0.75), moderately dissimilar (0.25-0.50), and extremely dissimilar (0.00-0.25). *Sympegma regelii*, *Reaumuria songarica*, *Ephedra przewalskii*, *Nitraria sphaerocarpa*, and *Kalidium foliatum* communities showed high similarity (>0.50), wide distribution, strong adaptability, and broad niche breadth.

3.2 Integrated Effects of Environmental Factors on Diversity Patterns

Species diversity distribution in the study area is influenced by the Altun, Qilian, Mazong, and Beishan Mountains, which redistribute water and temperature, creating vertical zonation with significant variation along altitudinal and latitudinal gradients but unclear longitudinal patterns. Diversity indices showed unimodal patterns along altitude but significant increasing trends along latitude. Altitude-induced changes in precipitation and temperature are primary drivers of community composition and diversity.

Previous studies indicate that higher precipitation increases diversity, and temperature decreases by 0.6 °C per 100 m altitude increase should reduce diversity. However, this study found that precipitation and temperature changes due to altitude were insufficient to significantly affect species diversity, suggesting that microhabitat heterogeneity exerts stronger influence than climatic factors at this scale. While temperature and moisture are important at large scales, at smaller scales species diversity is more susceptible to microhabitat heterogeneity, resulting in scale-dependent responses to environmental factors. For plants adapted to harsh desert gobi conditions, only community coverage responded significantly to precipitation and temperature. Due to scarce rainfall and lack of ephemeral plants, dominant species have established stable physiological regulation mechanisms. Consequently, species diversity did not increase significantly with precipitation or decrease significantly with temperature, instead showing distinct vertical (altitudinal) and latitudinal distribution patterns.

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Note: Figure translations are in progress. See original paper for figures.