Postprint of a Study on the Indicator Properties of Pollen for Vegetation in the Western Junggar Basin

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Abstract

Based on vegetation survey and surface pollen data from 46 quadrats in the western Junggar Basin, we estimated the association index (A), under-representation index (U), over-representation index (O), representation coefficient (R), mean percentage of a pollen type when the plant is absent in the quadrat (Ma), mean percentage of a pollen type when the plant is present in the quadrat (Mp), and similarity coefficient between pollen assemblages and plant communities (CC) for 19 major pollen types, to quantitatively describe the indicative significance of pollen to vegetation. The results show that: Group 1 includes Chenopodiaceae, with an A value of 1.0, O and U values of 0, an R value of 12.5, Mp much greater than Ma, showing clear indicative significance for vegetation; Group 2 includes Artemisia and Ephedra, with A values between 0.1 and 0.4, O values between 0.6 and 0.9, U values of 0, R values greater than 18.5, and differences between Mp and Ma of 3.6%–12.1%, showing relatively clear indicative significance for vegetation; Group 3 includes Nitraria, Liliaceae, Lamiaceae, Fabaceae, Poaceae, Asteraceae, Polygonaceae, Ranunculaceae, Rosaceae, Apiaceae, Cyperaceae, Brassicaceae, Caryophyllaceae, Convolvulaceae, Urticaceae, and Boraginaceae, with A values less than 0.6, U values between 0.2 and 0.9, O values between 0.1 and 1.0, R values less than 4.0, differences between Mp and Ma of less than 4.9%, showing unclear indicative significance for vegetation. The research results can provide a reference basis for accurately reconstructing paleovegetation using fossil pollen data.

Full Text

Study on the Indicative Significance of Pollen to Vegetation in Western Junggar Basin

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Abstract

Based on vegetation surveys and surface pollen data from 46 sampling sites in the western Junggar Basin of Xinjiang, this study quantitatively estimated several representative indices for 19 major pollen types, including the association index (A), underrepresentation index (U), overrepresentation index (O), representative coefficient (R), mean pollen percentage in the absence of vegetation (Ma), mean pollen percentage in the presence of vegetation (Mp), and the similarity coefficient between pollen assemblage and plant community (CC). The results indicate that these pollen taxa can be divided into three distinct groups. The first group comprises Chenopodiaceae, with an A value of 1.0, U and O values of 0, and an R value of 12.5; the Mp value is substantially higher than Ma, demonstrating clear overrepresentation and strong indicative significance for vegetation. The second group includes Artemisia and Ephedra, with A values ranging from 0.1 to 0.4, O values between 0.6 and 0.9, U values of 0, and R values exceeding 18.5; the difference between Mp and Ma ranges from 3.6% to 12.1%, indicating a robust correlation between pollen and vegetation. The third group encompasses Nitraria, Liliaceae, Labiatae, Fabaceae, Poaceae, Asteraceae, Polygonaceae, Ranunculaceae, Rosaceae, Umbelliferae, Cyperaceae, Brassicaceae, Caryophyllaceae, Convolvulaceae, Urticaceae, and Boraginaceae, characterized by A values below 0.6, U values between 0.2 and 0.9, O values between 0.1 and 1.0, and R values less than 4.0; the Mp-Ma difference is less than 4.9%, suggesting weak correlation and unclear indicative relationships. These findings provide a reliable reference for accurately reconstructing paleovegetation using fossil pollen data in this region.

Keywords: pollen; vegetation; representative index; similarity coefficient; Junggar Basin

1. Introduction

Pollen analysis serves as a primary method for reconstructing paleovegetation floristics and analyzing spatiotemporal evolution of vegetation types. However, pollen assemblages are significantly influenced by numerous factors including pollen productivity, dispersal mechanisms, plant biological characteristics, climatic conditions, and depositional environment, rendering the relationship between pollen and vegetation highly complex. Consequently, vegetation information reflected by different pollen combinations often differs substantially from actual conditions, necessitating quantitative investigations of pollen-vegetation relationships.

Davis first proposed the concept of the representative coefficient (R) to quantitatively describe pollen-vegetation relationships. Since R values are substantially affected by different study areas and vegetation zones and fail to account for exotic pollen influences, Davis subsequently introduced the association index (A), underrepresentation index (U), and overrepresentation index (O). These representative indices are influenced solely by pollen dispersal characteristics, yielding relatively stable values applicable across various spatial scales—suitable for both large-scale investigations of zonal vegetation and surface pollen spectra, and small-scale studies of pollen assemblage characteristics across different plant communities.

International research employing representative indices has primarily focused on America and Europe, while Chinese studies are predominantly distributed in eastern desert regions, North China, and Central China. In Xinjiang, located in northwestern China, existing research has primarily concentrated on R value calculations, with comprehensive quantitative investigations of multiple representative indices remaining relatively scarce. Xinjiang represents a typical arid and semi-arid region in Northwest China, where vegetation is highly sensitive to environmental changes. Seasonal rivers and strong winds create complex pollen dispersal mechanisms, making the representative relationship between pollen and vegetation a focal research topic. Therefore, this study focuses on the western Junggar Basin in Xinjiang, employing representative indices to quantitatively describe pollen indicative significance for vegetation, thereby providing a basis for paleovegetation reconstruction using pollen data.

1.1 Study Area Overview

The study area encompasses Bortala Mongolian Autonomous Prefecture and its surrounding region in western Xinjiang, situated along China's northwestern border adjacent to Kazakhstan. The region extends from Bole City in the west to Shihezi City in the east, reaches Tacheng City in the north, and extends to Yining City in the south, forming part of the Northern Tianshan geosynclinal fold belt. The area lies between 44°02 ~45°23 N and 79°53 ~83°53 E, with elevations ranging up to 2674 m and terrain sloping from high in the west to low in the east. The geomorphology comprises three major units: the Biezhentao Mountains, the Bortala Valley and Ebinur Basin, and the Alatao Mountains.

Located far from the ocean, the region features a northern temperate continental climate with pronounced aridity, abundant sunlight, and large annual and diurnal temperature variations. The mean annual temperature is 4–9 °C, with annual precipitation of 90–500 mm that is unevenly distributed and subject to high evaporation rates. The Bortala region hosts over 200 plant species, including nationally protected species, with dominant vegetation types including *Populus euphratica*, *Haloxylon persicum*, *Ephedra intermedia*, *Cistanche deserticola*, *Glycyrrhiza uralensis*, *Calligonum mongolicum*, *Saussurea involucrata*, and *Gentiana macrophylla*. The predominant plant families are Poaceae, Chenopodiaceae, Artemisia, Caragana, Stipa, Potentilla, Ephedra, and Haloxylon.

1.2 Field Sample Collection

During 2014–2015, simultaneous surface soil sampling and vegetation community surveys were conducted. Considering elevation, human activity, and vegetation zones, surface pollen samples were collected using the plum-blossom sampling method (collecting from four corners and the center of each quadrat, then mixing uniformly). Each sample weighed 50–100 g, with GPS positioning and statistical recording of plant species names, coverage, and abundance in the vicinity of each sampling point. A total of 46 surface pollen samples were collected; sampling point coordinates and vegetation profiles are shown in [Figure 4: see original paper] and .

1.3 Sample and Data Processing

Laboratory processing of surface soil samples aimed to remove impurities and extract pollen grains through acid-alkali treatment and heavy liquid flotation. Pollen identification and counting were performed using an optical biological microscope, with over 300 pollen grains counted per sample. The study calculated the association index (A), underrepresentation index (U), overrepresentation index (O), representative coefficient (R), mean pollen percentage in the absence of vegetation (Ma), and mean pollen percentage in the presence of vegetation (Mp) for each sample. Niu et al. have previously described the pollen assemblage characteristics, Artemisia/Chenopodiaceae ratios, and related information for all samples: arboreal pollen is dominated by Pinus and Picea, with percentages not exceeding 21.20%; shrub pollen is dominated by Ephedra and Rosaceae, with Ephedra pollen percentages around 47.89% (exceeding 80% at some sites) and Rosaceae pollen around 8.32%; herbaceous pollen is dominated by Chenopodiaceae and Artemisia, with Chenopodiaceae pollen percentages exceeding 50% at most sites (surpassing 90% at some) and Artemisia pollen percentages between 10–40%; Poaceae, Cyperaceae, and Asteraceae pollen percentages are around 10%, with other herbaceous pollen types below 5%.

The representative indices were calculated according to Davis's formulas:

Where: - P_{ij} represents the percentage of a given pollen type in sample i where the corresponding plant is present in the vegetation - V_{ij} represents the coverage of that plant in sample i - P_i represents the percentage of the pollen type in sample i - a represents the number of taxa with only surface pollen present - b represents the number of taxa with only plants present - c represents the number of taxa with both surface pollen and plants present

2. Results

2.1 Pollen Composition Characteristics

The 46 samples yielded 19 pollen types, including Fabaceae, Nitraria, Chenopodiaceae, Poaceae, Artemisia, Brassicaceae, Asteraceae, Ephedra, Labiatae, Polygonaceae, Ranunculaceae, Rosaceae, Umbelliferae, Cyperaceae, Caryophyllaceae, Convolvulaceae, Urticaceae, Liliaceae, and Boraginaceae.

2.2 Pollen Indicative Significance for Vegetation

To quantitatively estimate the representativeness of different pollen types for vegetation, A, O, U, R, Ma, Mp, and CC values were calculated for the 19 pollen types, revealing three distinct groups:

Group 1 includes Chenopodiaceae, with A = 1.0, O = U = 0, and R = 12.5. The Mp value substantially exceeds Ma, indicating strong correlation between pollen and vegetation and clear overrepresentation.

Group 2 comprises Artemisia and Ephedra, with A values of 0.1–0.4, O values of 0.6–0.9, U = 0, and R > 18.5. The Mp-Ma differences range from 3.6% to 12.1%, demonstrating strong association and clear indicative significance for vegetation distribution.

Group 3 includes Nitraria, Liliaceae, Labiatae, Fabaceae, Poaceae, Asteraceae, Polygonaceae, Ranunculaceae, Rosaceae, Umbelliferae, Cyperaceae, Brassicaceae, Caryophyllaceae, Convolvulaceae, Urticaceae, and Boraginaceae. Except for Poaceae, all have A < 0.6, U = 0.2–0.9, O = 0.1–1.0, and R < 4.0. Poaceae shows A = 0.6, O = U = 0.2, and R = 0.1, indicating low representativeness and weak correlation with vegetation.

3. Discussion

The similarity coefficient between plant communities and surface pollen ranges from -0.34 to 0.29, comparable to Li et al.'s study in eastern Chinese desert regions (0.09–1.00) but lower than values from the Northeast China Transect (0.29–0.80), suggesting the presence of exotic pollen. In arid regions with relatively flat terrain and windy conditions, pollen is easily transported over long distances. Ephedra pollen appears in most samples, yet some high-elevation sites lack Ephedra vegetation nearby, likely due to valley updrafts transporting pollen from lower elevations. Soil properties such as pH, moisture, and redox conditions also influence pollen content.

Poaceae pollen has A = 0.6, O = U = 0.2, and R = 0.1, indicating low representativeness related to low pollen production. With shallow root systems closely tied to moisture conditions, Poaceae typically indicates environmental humidity and represents dominant species in grassland regions. Its weak dispersal capacity concentrates pollen near parent plants. Despite containing some exotic pollen, the pollen assemblage reflects overall vegetation community characteristics, with shared pollen-vegetation taxa exceeding 60%.

Chenopodiaceae pollen shows A = 1.0, O = U = 0, and R = 12.5, with Mp substantially higher than Ma, demonstrating strong overrepresentation consistent with desert steppe region studies. Artemisia and Ephedra, dominant in arid and semi-arid regions, show low A values (0.1–0.4), U = 0, O = 0.6–0.9, and R > 18.5. Their R values exceed those in eastern Chinese desert regions, indicating overrepresentation consistent with previous research. Artemisia and Chenopodiaceae pollen, characterized by high production, strong dispersal, and good preservation, typically show overrepresentation in Asian arid and semi-arid surface pollen assemblages. Studies indicate that when their combined percentage exceeds 50%, they serve as important indicators for desert vegetation and past humidity changes.

Cyperaceae pollen has A = 0.2, O = 0.2, U = 0.2, and R = 0.1. With thin exines that are poorly preserved, Cyperaceae pollen-vegetation relationships show weak correlation. Liliaceae, Polygonaceae, Ranunculaceae, Caryophyllaceae, Convolvulaceae, Nitraria, Urticaceae, and Boraginaceae have A < 0.2, with O and U < 0.2 and R < 0.1, all showing low representativeness. Asteraceae, Labiatae, Fabaceae, Umbelliferae, Brassicaceae, and Rosaceae pollen also show A < 0.2, O and U < 0.2, and R < 0.1, indicating low indicative significance. These taxa exhibit varying representativeness across regions—for example, Asteraceae shows better representation where parent plants are present due to low-growing habits concentrating pollen near the ground. In Caragana shrublands and coniferous-broadleaf mixed forests, Fabaceae pollen corresponds well with vegetation. Nitraria distribution is strongly influenced by water sources; the presence of the Ebinur Lake (the largest lake in the Junggar Basin) and the Bortala River flowing through the region contributes to Nitraria's low representation. These differences in pollen representation primarily reflect variations in regional climate, vegetation, and topography.

While R values are influenced by quadrat statistics and vegetation coverage, they remain relatively stable with sufficient sample numbers and similar vegetation composition. Pollen representation is determined by plant characteristics and dispersal properties. The overall R values in this study area are relatively high, but local climatic differences and human activities affecting pollen dispersal result in significant vegetation variation, consistent with previous desert region studies.

4. Conclusion

Based on calculated A, O, U, R, Ma, and Mp values for 19 major pollen types, three groups can be distinguished:

Group 1 (Chenopodiaceae) shows A = 1.0, U = O = 0, and R = 12.5, with pollen strongly overrepresenting vegetation and providing clear indication.

Group 2 (Artemisia and Ephedra) has A > 0.1, U = 0, O > 0.6, R > 18.5, and Mp-Ma differences of 3.6%–12.1%, showing strong correlation and clear indicative significance for vegetation.

Group 3 (Nitraria, Liliaceae, Labiatae, Fabaceae, Poaceae, Asteraceae, Polygonaceae, Ranunculaceae, Rosaceae, Umbelliferae, Cyperaceae, Brassicaceae, Caryophyllaceae, Convolvulaceae, Urticaceae, Boraginaceae) shows A < 0.6, U > 0.2, O > 0.1, and R < 4.0, with Mp-Ma differences < 4.9%, indicating unclear pollen-vegetation relationships.

Overall, these results show high consistency with previous studies when considering the study area's natural conditions and plant characteristics, providing a reliable reference for paleovegetation reconstruction in the western Junggar Basin.

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