The Role of Environmental Factors and Interspecific Competition in Community Diversity Patterns (Postprint)

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Abstract

Taking the hill slopes of long-term enclosed grassland in the typical steppe of Inner Mongolia as the study area, six transects were uniformly established along the slope, totaling 96 quadrats, to investigate the effects of slope position on species diversity and functional diversity of typical steppe communities, and to discuss the roles of environmental factors and interspecific competition in shaping the patterns of these two dimensions of community diversity. The results showed that: (1) The trends of species diversity and functional diversity along the slope position were consistent. With increasing slope position, both species richness and functional richness of the community decreased monotonically, while species evenness, species dominance, functional evenness, and functional dispersion all initially increased and then decreased. (2) From the perspective of the entire slope position, soil total phosphorus content was the main factor affecting community species richness and was significantly correlated with functional richness; interspecific competition was an important factor influencing species evenness, species dominance, and functional dispersion, and was significantly correlated with functional evenness. (3) Community species diversity and functional diversity on the upper slope position were mainly influenced by the combined effects of interspecific competition and environmental factors, while on the lower slope position, they were mainly influenced by interspecific competition. Therefore, when investigating the patterns of community biodiversity change, the combined effects of environmental and biological factors should be comprehensively considered.

Full Text

Preamble

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1 Introduction

This study investigates the relationship between species diversity and functional diversity () in grassland communities. The objectives are: (1) to examine the effects of slope position on species diversity and functional diversity, and (2) to analyze the influence of environmental factors and interspecific competition on these two dimensions of biodiversity.

2 Materials and Methods

2.1 Study Area

The research was conducted in a typical grassland enclosure in Inner Mongolia. Six transects were established along the slope, with a total of 96 sample plots. Each transect measured 12 m in length, divided into 6 sections (1-6). Sections 1–3 represented the upper slope, while sections 4–6 represented the lower slope. The vertical height of the slope was 31 m. Sample plots of 1 m × 1 m were set up at 1 m intervals along each transect, yielding 16 plots per transect and 96 plots total.

2.2 Sample Collection and Measurement

Vegetation surveys and soil sampling were conducted in mid-August 2014. For each plot, we recorded species composition, height, coverage, and density. Aboveground biomass was harvested and dried at 60°C for 72 hours to determine dry weight. Soil samples were collected from the 0–20 cm layer and analyzed for total nitrogen, total phosphorus, available nitrogen, available phosphorus, and organic matter content. A LI-3100 leaf area meter was used for physiological measurements.

2.3 Diversity Index Calculation

Species diversity indices were calculated as follows:

Shannon-Wiener index:

$$H = -\sum p_i \times \ln(p_i)$$

Simpson index:

$$D = 1 - \sum p_i^2$$

where $p_i = n_i/N$, n_i is the importance value of species i, and N is the sum of importance values for all species.

2.4 Statistical Analysis

Functional diversity was quantified using two indices: functional evenness (FEve) and functional dispersion (FDis). Pearson correlation analysis was performed to examine relationships between diversity indices and environmental factors. Stepwise regression analysis was used to identify key influencing factors. All statistical analyses were conducted using SPSS software, with significance set at $P < 0.05$.

3 Results

3.1 Correlation Analysis

Correlation analysis revealed significant relationships between diversity indices and slope position (Table 2). Species richness and functional richness showed negative correlations with slope position ($r = -0.790$ and $r = -0.850$, respectively, $P < 0.01$). Functional evenness and functional dispersion initially increased then decreased with slope position. Shannon-Wiener index and Simpson index exhibited similar trends, with correlation coefficients of -0.823 and -0.744 ($P < 0.01$) for the lower slope position.

Table 2 Functional diversity multiple stepwise regression and correlation analysis results

Index	Slope Position	Functional Evenness	Functional Dispersion
Species Richness	-0.790^{**}	0.211^{*}	-0.408^{**}
Functional Richness	-0.850^{**}	-0.378^{**}	-0.411^{**}
Shannon-Wiener Index	-0.823^{**}	0.041	-0.690^{**}
Simpson Index	-0.744^{**}	-0.378^{**}	-0.438^{**}

- $P < 0.05$, ** $P < 0.01$

4 Discussion

4.1 Effects of Environmental Factors and Interspecific Competition

The total phosphorus content across the slope was the primary factor affecting species richness, correlating significantly with functional richness. Interspecific competition was the key factor influencing species evenness, species dominance, functional dispersion, and functional evenness. In the upper slope position, both environmental factors and interspecific competition jointly affected community diversity, whereas in the lower slope position, interspecific competition was the dominant factor.

These findings align with Tilman' s resource competition theory, which posits that community structure is shaped by resource availability and competitive interactions. The observed patterns support the hypothesis that functional diversity reflects the distribution of species traits in niche space, while species diversity represents the number and abundance of species. The joint effects of environmental filtering and competitive exclusion create distinct diversity patterns along the slope gradient.

The significant correlation between species diversity and functional diversity ($r = 0.762$, $P < 0.01$) indicates that communities with higher species richness also exhibit greater functional richness. However, the relationship is mediated by slope position, suggesting that topographic heterogeneity modifies the biodiversity-environment relationship. This has important implications for grassland management and conservation in arid and semi-arid regions.

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