Species Diversity and Coexistence Patterns at the Patch Scale in Stipa breviflora Desert Steppe (Postprint)

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Abstract

Elucidating species coexistence patterns at the patch scale is of great significance for deeply understanding the maintenance mechanisms of biodiversity in fragmented desert steppe grasslands. Based on the degree of soil habitat degradation in patches, three typical community patches in Stipa breviflora desert steppe were selected as research objects to conduct comparative analyses of species composition, diversity, and coexistence relationship patterns among different patches. The results showed that: Patch A belonged to a monodominant Stipa breviflora community; Patch B was a Stipa breviflora + Astragalus melilotoides community; Patch C was a Sophora alopecuroides + Cynanchum komarovii + Artemisia scoparia community. In terms of community structure, the diversity of Patch A and Patch B was similar, both being higher than that of Patch C without Stipa breviflora growth. Analysis results based on null models showed that the complexity and intensity of species coexistence patterns were: Patch A > Patch B > Patch C, with a clear downward trend. Among the 16 significant species pairs in Patch A, 4 were significantly competitive relationships, while the species pairs in Patch C decreased to 7, with only the Artemisia scoparia and Sophora alopecuroides pair being a significant competitive relationship. Conclusion: This indicates that non-desertified soil habitat patches are an important prerequisite for the maintenance of biodiversity in fragmented desert steppe grasslands, and the degradation of soil habitats significantly reduces the complexity of community organization and the intensity of species interactions within patches, which is not conducive to community self-maintenance.

Full Text

Species Diversity and Co-Occurrence Pattern at Patch Scale in *Stipa breviflora* Desert Steppe

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Abstract: Clarifying the species co-occurrence pattern at patch scale is of important significance for understanding the maintenance mechanism of biodiversity in desert steppe fragmentation. According to the degree of soil habitat degradation at patch scale, this study contrasted and examined the species composition and diversity of different patches and the species co-occurrence pattern based on three typical patches in a *Stipa breviflora* desert steppe. The results indicated that: (1) Patch A was a consociation and belonged to a community of *S. breviflora*. Patch B was a community of *S. breviflora* and *Astragalus melilotoides*. And Patch C was a community of *Sophora alopecuroides* + *Cynanchum komarovii* + *Artemisia scoparia*; (2) In community structure, the diversity of Patch A and Patch B was similar and higher than that of Patch C where *S. breviflora* grew; (3) The analyzed results based on the null model showed that the complexity and intensity of species co-occurrence patterns was in an order of Patch A > Patch B > Patch C. Four of the 16 significant species pairs in patch A had a significant competitive relation, while the species pairs in patch C were reduced to 7 groups, and there was only one significant competitive species pair (*A. scoparia* and *S. alopecuroides*) in patch C. Therefore, non-desertified soil habitat patches were the important prerequisite for the biodiversity maintenance of desert steppe fragmentation. The non-desertified soil habitat reduced significantly the complexity of community structure within patches and the intensity of interaction between species, which was unconducive to the self-maintenance of the community.

Keywords: desert steppe; *Stipa breviflora*; patch scale; importance value; species diversity; co-occurrence pattern; Ningxia

1. Study Area

The study area is located in the *Stipa breviflora* desert steppe region (37°04 - 38°10 N, 106°30 -107°47 E), characterized by a typical temperate continental climate. The mean annual temperature is 8.4°C, the frost-free period is 160 days, and annual precipitation ranges from 250 to 350 mm, concentrated primarily in July through September. The vegetation consists mainly of temperate steppe communities dominated by *Stipa breviflora*.

2. Methods

Species diversity indices were calculated for each patch type, including richness index (R), Simpson index, Shannon-Wiener index, and Pielou index. Pairwise analysis of species co-occurrence patterns was conducted using null models to assess significant associations.

3. Results

Table 3 shows the differences in species diversity indices among different patch types. The richness index, Simpson index, Shannon-Wiener index, and Pielou index were all significantly higher in Patches A and B compared to Patch C ($P < 0.05$). Specifically, Patch A exhibited values of 7.17 ± 0.27, 0.79 ± 0.02, 2.48 ± 0.06, and 1.27 ± 0.02 for the four indices respectively, while Patch B showed similar values. Patch C, however, displayed significantly lower diversity across all measures.

Table 4 presents the pairwise analysis of significant plant species in different patch types. The standardized effect size (SES) values indicate the strength and direction of species associations. In Patch A, 16 species pairs showed significant co-occurrence patterns, with four pairs exhibiting significant competitive relationships. Patch B showed intermediate levels of species interactions, while Patch C had only 7 significant species pairs, with just one competitive pair (*Artemisia scoparia* and *Sophora alopecuroides*).

Fig. 1 illustrates the frequency distribution of standardized effect sizes among coexisting species pairs. The distribution patterns differed markedly among patches, with Patch A showing the widest range of effect sizes, indicating more complex species interactions.

4. Discussion

The analysis revealed that non-desertified soil habitat patches are crucial for maintaining biodiversity in fragmented desert steppe ecosystems. The complexity and intensity of species co-occurrence patterns followed the order: Patch A > Patch B > Patch C, corresponding to the degree of habitat degradation. In Patch A, which represented intact habitat, competitive interactions among species were more frequent and intense, suggesting a well-structured community with established niche relationships. Conversely, Patch C, representing

degraded habitat, showed simplified community structure with fewer significant species interactions.

The null model analysis demonstrated that as soil habitat degradation increased, the complexity of community structure within patches and the intensity of inter-specific interactions decreased significantly. This reduction in biotic interactions is unconducive to community self-maintenance and may accelerate degradation processes. The findings support the hypothesis that preserving non-desertified patches is essential for biodiversity conservation in desert steppe ecosystems.

Previous studies have shown similar patterns in other grassland ecosystems [14, 15, 16]. The importance value of dominant species such as *Stipa breviflora* and *Astragalus melilotoides* decreased significantly in degraded patches, while stress-tolerant species like *Sophora alopecuroides* and *Artemisia scoparia* became more prominent [16]. This shift in species composition reflects the community' s response to environmental stress and habitat fragmentation.

The standardized effect size analysis, following Pianka' s niche overlap index [21], provides robust evidence for the changing patterns of species interactions across degradation gradients. The reduced number of significant species pairs in degraded patches indicates weakened biotic interactions, which may impair ecosystem stability and resilience.

5. Conclusion

Non-desertified soil habitat patches represent a critical prerequisite for biodiversity maintenance in desert steppe fragmentation. Habitat degradation significantly reduces community structural complexity and the intensity of species interactions, thereby compromising community self-maintenance. Conservation efforts should prioritize the protection of intact patches to preserve species diversity and ecological functions in desert steppe ecosystems.

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