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The applicability of the species pool hypothesis to community diversity in the Inner Mongolia grassland along a mean annual precipitation gradient

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ABSTRACT

Exploring the underlying mechanisms of community diversity is a key issue in ecology and conservation biology. Community diversity studies typically focus on local processes, but these factors cannot completely explain community diversity. Many previous studies have shown that species richness can be quite different among communities with similar habitats. Therefore, the importance of regional processes has gradually been considered, and many hypotheses based on regional processes have been proposed. The species pool hypothesis developed by Zobel et al. is one of the most important theoretical developments in the field of community diversity. The species pool hypothesis suggests that community diversity is not only associated with contemporary environmental factors and local ecological processes (e.g., competition, predation, resources, spread, and interference), but is also limited by the regional species pool. The regional species pool is the set of species in a certain region that are capable of coexisting in a target community, which is shaped by historical (e.g., glaciation and geological age) and regional processes (e.g., speciation, immigration, dispersion, and extinction). To explore the applicability of the species pool hypothesis to community diversity in the Inner Mongolia grassland, we investigated the species diversity in the grassland region from late July to mid-August in 2012, when the grassland community biomass was at its peak. In this region, precipitation is considered the most important environmental factor affecting species diversity. Therefore, we established 192 field sites in the Inner Mongolia grassland along a gradient of mean annual precipitation. The position of each field site was located using GPS. At each site, an area of 10 m × 10 m was delineated, and 10 plots of 1 m × 1 m were randomly placed in the delineated area to survey all plant species. Based on these data, the relationships between regional diversity (gamma diversity) and community diversity (alpha diversity) were analyzed along seven mean annual precipitation (MAP) gradients. Gamma diversity is the total species richness at a site. Alpha diversity is defined as the mean species richness (number) for the 10 plots at a site. The correlation coefficient between these two diversity indices was used to verify the applicability of the species pool hypothesis. A few key results were obtained. (1) Both alpha diversity and gamma diversity increased significantly with MAP in the Inner Mongolia grassland. (2) Gamma diversity and alpha diversity showed a significant positive linear relationship under different gradients of MAP, which reveals that the species pool hypothesis adequately explained community diversity along different precipitation gradients. (3) The effect of the regional species pool on community species diversity weakened as the MAP increased, which explains the decrease in the applicability of the species pool hypothesis as MAP increased. (4) Exploring the relationship between gamma diversity and alpha diversity represents an effective method for determining the impact of the species pool on community diversity. This study contributes to the theory regarding the mechanisms that maintain community diversity. It also has practical applications for the protection of diversity in the Inner Mongolia grassland.

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1. Introduction

As the basic level of biodiversity, species diversity is one of the key issues in ecology. Therefore, attention has been extensively paid to the interpretation of species diversity [1]. The community species diversity is influenced by a series of factors. Previous studies on this problem mainly focused on local processes, such as, predation, competition, resource supply, spread, interference [2–4]. These hypotheses have preferably explained the community species diversity [5]. However, the local processes cannot completely explain why species richness can be quite different among communities with similar habitats [6–7]. Accordingly, the impact of regional processes on the community species diversity has been gradually considered [8–11], and a new species pool hypothesis based on this has been emerged. Cornell and Lawton [10], Zobel [11], et al. further developed this hypothesis which basically considers that community diversity is not only related to local environmental conditions and ecological processes (e.g., competition and predation), but also affected by potential species pool. The species pool refers to the set of potential species in a certain region that are capable of coexisting in a target community [1], which is determined by historical and regional processes [7–9].

The Inner Mongolia grassland, located in Inner Mongolia Autonomous Region, China, is a dominant component of the Eurasian grassland [12]. Owing to the habitat heterogeneity and the unique evolutionary history, diverse plant species can be found in the region. According to incomplete statistics, over 2300 species of vascular plants grow in the Inner Mongolia grassland [13]. Therefore, the region has been ranked at the second in the world after Savanna in Africa regarding the diversity of indigenous plants [14]. Many previous investigations generally focus on local processes, while the influence of regional species pool on the species diversity in the Inner Mongolia grassland has rarely been reported. The gamma diversity and alpha diversity developed by Whittaker [15] individually refer to the number of species and the community diversity in a certain region. Given that precipitation is the main factor affecting species diversity in this region [16–17], this paper set up 192 field sites in the Inner Mongolia grassland along seven gradients of mean annual precipitation (MAP) to explore the relationship between the gamma diversity and the alpha diversity. Afterwards, the correlation coefficient between these two diversity indices was applied to validate the applicability of the species pool hypothesis in maintaining the community diversity of the region. This paper enriches the theory concerning the mechanisms that maintain community diversity, and also provides a scientific basis for the protection of biodiversity in the Inner Mongolia grassland.

2. General situation of the surveying area

We surveyed the grassland species diversity in the whole region of the Inner Mongolia grassland in northern China. The region stretches from latitudes 41.31° N to 50.78° N and longitudes 108.16° E to 120.39° E with elevation ranging from 532 to 1725 m above sea level. It is mainly composed of high plains, terraces and mountains. From southeast to northwest, the mean annual temperature and precipitation decline from 6.7 °C to −3 °C and from 450 mm to 150 mm, respectively. Chernozem, chestnut soil and brown soil are basically developed in the region, on which correspondingly distributed meadow steppe, typical steppe and desert steppe.

3. Methods

3.1. Field sites

The species diversity in the grassland region was investigated from late July to mid-August in 2012, during which the grassland showed the maximum community biomass. Along the precipitation gradients, 192 field sites of 10 m × 10 m were established from west to east in the Inner Mongolia grassland, as shown in Fig. 1. To eliminate the influence of grazing on the species diversity, all the field sites were set in the grassland which has been enclosed for many years. The position of each field site was located using GPS. At each site, 10 plots of 1 m × 1 m were randomly placed to record all plant species.

3.2. Data processing

Based on the methods proposed by Crist et al. [18] and Chiarucci et al. [19], the alpha diversity is defined as the mean species number for the 10 plots at a site. Therein, α presents the alpha diversity and Si shows the species number for a plot.

$$\alpha = \frac{1}{10}\sum_{i=1}^{10} Si \ ;$$

The gamma diversity refers to the total species number in the 10 plots.

The MAP data for each site were acquired from current monitoring data from 1950 to 2000 downloaded from the WORLDCLIM site (http://www.worldclim.org/) with a spatial resolution of arc30s. The MAP in the surveying region was divided into seven gradients: MAP < 150 mm, 150 ≤ MAP < 200 mm, 200 ≤ MAP < 250 mm, 250 ≤ MAP < 300 mm, 300 ≤ MAP < 350 mm, 350 ≤ MAP <400 mm and MAP ≥ 400 mm.

3.3. Data analysis

The gamma diversity means the species number in a region, which can be used to represent the regional species pool. The alpha diversity refers to the species richness in a community and is mainly applied to represent the community diversity. Based on the analysis of the relationship between the gamma diversity and the alpha diversity, this paper validated the applicability of the species pool hypothesis in maintaining the community diversity according to the correlation coefficient between the two indices. Initially, the variation of the alpha diversity and the gamma diversity with MAP was determined by using a simple linear regression method. Then, simple linear regression analysis was performed to discuss the relationship between the gamma diversity and the alpha diversity along the seven gradients of MAP. If they showed a significant positive linear relationship, the species pool hypothesis adequately explained community diversity in this region; otherwise, this hypothesis was not applicable. Lastly, the slope of the simple linear regression analysis was utilized to represent the influence degree of the gamma diversity on the alpha diversity: the larger the slope, the larger the influence degree was, under which circumstance the hypothesis was more applicable in this region. According to the slopes of the seven gradients of MAP, the variation trend of the influence of the gamma diversity on the alpha diversity with MAP was analyzed to determine the applicability of the special pool hypothesis as MAP increased.

All the analyses were performed with spss 21.

4. Results

4.1. Trend of alpha diversity and gamma diversity along MAP in the Inner Mongolia grassland

As shown in Fig. 2, both the alpha diversity and the gamma diversity increased with MAP in the Inner Mongolia grassland.

4.2. Relation between gamma diversity and alpha diversity under different gradients of MAP

It can be seen from Fig. 3 that the alpha diversity in any gradients of MAP grew as gamma diversity increased. Moreover, the two indices were in significant positive linear relation, which suggests that the