Scale dependence in desert plant diversity

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Abstract. The relationship between the number of species and the area sampled is one of the oldest and best-documented patterns in community ecology. An equation of the form \( S = cA^z \) describing more precisely the species–area relation for plant species in smaller area is proposed as a result of intensive examination of species presence. Several study and field data from a wild range of plant and animal taxa suggest that the slope, \( z \), of a graph of the logarithm of species richness against the logarithm of area is not a constant to the grassland or woodland community. We collected replicated and randomized plant data at 6 spatial scales from 1 m\(^2\) to 1 km\(^2\) in the desert region of northwest China to identify the scale dependence in desert plant biodiversity. The results showed that the slope of the log–log plot varied systematically with spatial scale. The value of \( z \) was high (0.37) at small scales from 1 to 10 m\(^2\) and it decreased with increased spatial scale subsequently. When spatial scales varied from 1 m\(^2\) to 1 km\(^2\), the value of \( z \) varied from 0.37 to 0.035, suggesting that desert plant diversity has strongly scale-dependence at the small scales (less than 100 m\(^2\)). The result is different from the research of grassland and woodland communities.

Introduction

Understanding the determinations of species richness is central to many questions in both pure and applied ecology (Crawley and Harral 2001). Changes in species richness at different spatial scales were determined by different factors and ecological processes. At the larger spatial scales and over the longest time scales, species richness is determined by rates of speciation and extinction (Rosenzweig 1995). At smaller spatial scales and over shorter periods of time, the number of species is determined by the birth, death, and dispersal rates of individuals interacting with populations of competitors, mutualists, and natural enemies (Pacala 1997). In all cases, however, the number of species depends on the area sampled, the absolute abundances of the species (Preston 1962a, b; Dony 1963; Williams 1964). The relationship between species richness and area is particularly important in biodiversity studies because it holds out the prospect of predicting species richness at large scales from data gathered relatively inexpensively at much smaller scales (Kunin 1998). It is conventional to use the power law \( S = cA^z \) to describe the relationship between species richness (\( S \)) and the area sampled (\( A \)). The exponent, \( z \)
value more truly reflects the species-richness of the community, it is close to 0.25 for several theoretical models and for much field data, but there are also data where $z$ is greater than 0.25 (e.g., on island, and at large scales generally), and data where the slope is less than 0.25 (e.g., with smaller, plant-sized quadrats) (Pidgeon and Ashby 1940; Preston 1960; Kilburn 1966). Crawley and Harral (2001) studied the flora of the county of Berkshire in southeast England about scale dependence in plant biodiversity, showing that the slope of the species-area relationship changes with spatial scale. For the small scales over which individual plants interact (square centimeter to square meter), $z$ is small ($0.1 < z < 0.2$) but strongly habitat-dependent. The most rapid changes in species richness ($0.4 < z < 0.6$) occur at intermediate scales (hectare to square kilometer) where whole new habitats are added as sample area is increased. At the largest spatial scales (10–100 km$^2$), $z$ is relatively small ($0.1 < z < 0.4$).

The species–area relation, formerly referred to as the species–area curve, is simply compilation of species numbers per unit area of a community. It could provide a most useful comparative measure of communities because it can be reduced to a simple mathematical expression that could well be a means of assessing environmental stress, understanding floristic history, and providing a clue to isolation time and evolutionary development (Kilburn 1966). Many studies concerning the relationship between the number of species and the area sampled focus mainly on the grassland and forest communities (Ma et al. 1997; Zhou et al. 2000; Crawley and Harral 2001). However, information on the species–area relationship in desert communities is lacking. Under the scenario of global desertification development, more and more attention will be given to desert plant biodiversity, distribution pattern and conservation. This paper uses vegetation data collected in desert region of northwest China to explore the species–area relationship in desert community.

Methods

Study sites

The study site (37°14′–39°48′ N, 101°47′–97°06′ E) is located in desert region in the middle of Gansu province (the middle reaches of Heihe River Basin) of northwest China (Figure 1). Average annual rainfall is 85–193 mm, 65% distributed mainly in summer showers of short duration. Mean annual evaporation ranges from 2000 to 2500 mm and annual average temperature is 7.6 °C. The selected sites are alluvial plain with relatively flat topography and altitudes from 1250 to 1500 m. The soils are sandy and sand loam texture. In August 2002, 10 undisturbed and different dominant species communities were selected for data collection. The dominant species include Salsola passerine Bunge, Artemisia anethifolia Weber, Halogeton arachnoideus Miq., Reaumuria soonggorica (Pall.) Maxim., Asterothamnus alyssoides (Turct.) Novopokr., Suaeda