

Distribution of Plant Species Richness along Elevation Gradient in Hubei Province, China

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Abstract

The plant species richness (spermatophyte) patterns along elevation gradient in Hubei province of China was studied, using published elevation range data. The result showed a hump-shaped distribution, with high species richness in the middle elevation range from 800 to 1400 m. The maximum value of species richness was observed at 1000 m, and this is accounted for about 52 % of the total number found in Hubei province. The observed pattern in the Hubei province is compared with reports from other regions, and is related to hypotheses published in the literature. Possible factors, such as resource availability, overlap of habitats, the total land area at each elevation band, hard boundary, and human activities, may underlie the patterns. Greater effort of conservation biodiversity in high species richness area in Hubei province should be made.

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Introduction

A fundamental characteristic of mountain ecosystems is the drastic change in vegetation as well as in climate from the base to the summit of mountain. Elevation gradients create varied climates, along with resultant soil differentiation, promote the diversification of plant species (Brown, 2001; Lomolino, 2001). Many studies have investigated species richness along elevation gradient across habits and taxa (Rahbek, 1995, 1997; Austrheim, 2002; Vetaas and Gerytnes, 2002; Sanders et al., 2003), as part of efforts to understand ecosystem effects on biodiversity and conservation of biodiversity (Tilman and Downing, 1994; Vetaas and Gerytnes, 2002). Furthermore, the observable associations between species distribution and elevation bands may help to understand the possible effects of climate change, e.g., by providing baseline information from which to measure or gauge the effect of climate change and anthropogenic changes on vegetation.

The regional patterns of species richness are a consequence of many interacting factors, such as plant productivity, competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables, and human activity (Woodward, 1988; Palmer, 1991; Eriksson, 1996; Zobel, 1997; Criddle et al., 2003). In general, as identified by Rahbek (1995, 1997), there are three main patterns: a monotonic decline in species richness from low to high elevation, a hump-shaped pattern with a maximum at mid-elevations, or essentially a constant from the lowlands to mid-elevations followed by a strong decline further up.

This study was conducted with the aim to investigate the main patterns of plant species richness (spermatophyte) along elevation gradient in Hubei province. Published data on distributions and elevation ranges of each plant species in Hubei province were used. The results

are in turn compared with the reports from other regions. Finally, what factors may underlie the patterns is discussed.

Materials and Methods:

Study region

The Hubei Province is chosen as the study region because of its rich mountain habitats and high plant species diversity. It is located in the center of China (29° 05' ~ 33° 20' N; 108° 21' ~ 116° 07' E). Of its total land area of 185,900 sq km, 55.5% is mountains, 24.5% hills and 20% plains. It has eight major mountain ranges: Shennong Jia (peak height: 3105 m), Julong (1852 m), Dabie (1729 m), Wudang (1612 m), Jiugong (1543 m), Tongbo (1140 m), Dahong (1055 m), and Jigong (744 m) (Atlas of China, 2000). The predominant geological compositions are of granite, schistose and sedimentary rocks. The climate is continental, subtropical and seasonal, with an annual precipitation of 800-1600 mm. The province, claiming a total of 5650 plant species (spermatophyte), is considered as one of the important center of biodiversity in China (Zheng, 1993). It is the native home to such important relic species as *Metasequoia glyptostrobodies* Hu et Cheng, *Ginkgo Biloba* L, and *Davidia involucrata* Bail.

Data source and Data analysis

Data on elevation ranges in the *Contemporary flora of spermatophyte plant species in Hubei province* (Zheng, 1993) was used in this study. The elevation gradient was divided into 15 200-m intervals between 400 and 3105 m a. s. l., with the starting interval at 0 – 400 m a. s. l. and the final one at 3000 – 3105 m a. s. l. This was due to fact that the lowland forest was transformed to agricultural land and according to the terrain of Hubei province.

Based on the information on the geographic range of each plant species in Hubei

province that described in this book, the presence of each species in every 200-m interval was recorded. Species richness here is defined as the total number of species present. Hence, the species richness for each of the elevation zones is the total number of species recorded as present within that band (i.e., gamma diversity, following Whittaker, 1972; Shimada and Wilson, 1985).

The patterns of species richness were showed in scatter plots, where horizontal axes are defined as elevation and the vertical axes as species richness.

Results and discussion

The patterns of plant species richness (spermatophyte) in Hubei province along elevation gradient is shown in Figure 1. There is a significant increasing trend in total species richness from 400 m to 1000 m a. s. l. From 1000 m to 3105 m, there is a clear decrease, except for a plateau between 1200 and 1600 m a. s. l. Thus, the high plant species richness in Hubei province is peaked at middle elevation range from 800 to 1400 m, with the maximum value observed at 1000 m. This value is accounted for about 52 % of the total number of spermatophyte found in Hubei province.

This falls within the general pattern of an initial increase in species richness with elevation, followed by a peak and then a decline with further increased elevation. It is similar to those found of forest tree species in the Qilian mountain which peaked at 2400-2800 m (Wang et al., 2003), of pteridophytes in Panama with maximum at 500-1500 m (Lellinger, 1985), of vascular plant species of semi-natural subalpine grasslands in Vang, Southern Norway (Austrheim, 2002), and of tropical rain forests species (Lieberman et al. 1996; Vazquez Garcia and Givnish, 1998). Further examples of species richness peaking at intermediate elevations were reported by Edwards and Armbruster (1989) along a steppe tundra gradient in Alaska, and by Shmida and Wilson (1985) along an elevational gradient in Israel. According to Vettas and Gerytnes (2002),

about half of the published studies showed a mid-elevation peak in plant species richness.

Vegetation interacts with topography and soils, modifying microsites and creating ecological niches for various plants and animals. As a result, animal or insect species richness often mirrors plant species richness along elevation gradients. For example, the ant species richness peaked at mid-elevation range as showed by a study on the patterns of ant species richness along elevational gradients in an arid ecosystem in Spring Mountains, Nevada, U. S.A (Sanders et al., 2003). Similar patterns were also reported in insects (McCoy, 1990) and in small mammals (Heaney 2001; Richart, 2001).

The distribution of species richness along elevation gradients is governed by a series of interacting biological, climatic and historical factors (Colwell and Lees, 2000). Further, elevation represents a complex gradient along which many environmental variables change simultaneously (Austin et al., 1996). Thus, the effect of each variable could be difficult to separate and these interacting factors would be difficult to disentangle. While the present study did not include a specific test on the mechanisms that resulted in the patterns of species richness in this study, the concordance of proposed hypotheses in the literature with this observed actual pattern was evaluated. Factors that might affect this pattern were also discussed.

Several hypotheses have been put forward to explain elevation patterns of species richness. For example, optimum humidity conditions at mid-elevations (Rahbek, 1995, 1997) and the high productivity in the mid-elevation region which resulted by optimal combination resource availability (Rosenzweig, 1995). This observed hump-shaped species richness patterns of spermatophyte in Hubei province is in accordance with the hypothesis of productivity and optimum resource combination in the intermediate portion of the elevation gradient. The

mid-elevation ranges with an optimal combination of environmental resource were more preferable for many species to coexist (Lomolino 2001; Brown, 2001), therefore, more species of spermatophyte was found in this elevation band in Hubei Province.

Few species are able to tolerate the entire spectrum of environment and range throughout the gradient (Pauses and Austin, 2001; Brown, 2001). Hence, species with elevational limited range always replace each other with some overlap along mountainside (Brown, 2001). A study of tree species distribution on Mt Emei in China, displayed a trend in which there is a unique set of temperature regimes that allow species usually associated with warmer temperatures to co-exist with species adapted to colder temperatures at higher elevations (Tang et al., 1997). This mixed community of low elevation and high elevation species has greater species richness than communities at lower or higher elevations. Such a tendency of overlapping habitats and resources in mid-elevation areas could be partially responsible for the high species richness of spermatophyte at mid-elevations in Hubeiprovince.

The major decline in species richness above 1600 m found in Hubei could be due in part to ecophysiological constrains, such a reduced growing season, low temperature and low ecosystem productivity in high elevation (Körner, 1998). In addition, the boundary effect could also influence the species richness at high elevation (Colwell and lees, 2000; Gerytnes and Vetaas, 2002). Boundary effect is defined in relation to the degree of species resistance to dispersals and survival (Colwell and Lees, 2000). Mountains can be represented as islands through their reduced connectivity to means of colonization by plants and animals. As elevation increases, the isolation of slopes from pathways of migration increases linearly. With a reduction in the channels available for immigration, there is a reduction in the number of species that occupy high elevation sites.

Moreover, a limited species pool of spermatophyte will also affect the species richness in high elevation, as environmental constraints are expected to exclude species from high elevation habitats (Körner, 1995).

Mountains generally have a conical shape and as the elevation increases, the area of the elevation band with certain set of environmental and climatic conditions decrease with increasing elevation. With a reduced area, there are fewer microsites for plants to occupy through the development of specific adaptive traits. The 200 m interval used in this analyses do not represent equal area because the topography of Hubei province. Therefore, the area effect could also account for the decline of species richness of spermatophyte in Hubei province in high elevation ranges (Rosenzweig, 1995; Zobel, 1997; Körner, 2000).

Other factors, such as soil fertility, topography may also affect the patterns of species richness along elevation gradient. In mountain regions, the pattern of different forest types and other communities often corresponds to elevation and topography. Variation in microclimate with topography and elevation is a major factor of species distribution within a forest landscape. Mark *et al* (2000) found topographic features (elevation, exposure and slope) to be responsible for the macroscale patterns of alpine vegetation distribution on Mount Armstrong in New Zealand.

Human activities, such as changes in land-use, have a long lasting and direct impact on species richness in mountain environments. A study conducted by Curtin (1995) in southwest Colorado demonstrated that species diversity in the subalpine at elevations between 3000-3200 m could be affected by human land use up to 110 years after the departure of the inhabitants. This study also showed that plant communities in high elevations are very sensitive to human disturbance.

In summary, the species richness of spermatophyte along elevation gradient in Hubei province is a hump-shaped distribution, with a high species richness in the middle elevation range from 800 to 1400 m. These possible factors that might affect this pattern were resource availability, overlap of habitats, land area, and human activities. The high species richness in the elevational range of 800 -1400 m means greater effort should be made focused on conservation on biodiversity of this area. Furthermore, our study could serve as baseline information to measure the effect of climate change. Further study on the factors that influences the species richness in Hubei province and the possible effects of climate change on the species richness patterns are needed.

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