

DISTRIBUTION OF PLANT SPECIES RICHNESS ALONG ELEVATION GRADIENT IN HUBEI PROVINCE, CHINA

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ABSTRACT: Plant species richness (spermatophyte) patterns along an elevation gradient in Hubei province of China were 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 meters. The maximum value of species richness was observed at 1000 meters, and this is accounted for about 52 percent 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 efforts in conserving biodiversity in the high species richness areas of Hubei province should be made.

Keywords: biodiversity, conservation, elevation gradient, Hubei province, species richness

1. 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 the mountains. Elevation gradients create varied climates, and a soil differentiation that may 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 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 is conducted with the aim to investigate the main patterns of spermatophyte richness 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.

2. 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 percent is mountains, 24.5 percent hills and 20 percent plains. It has eight major mountain ranges: Shennong Jia (peak height: 3105 meters), Julong (1852 meters), Dabie (1729 meters), Wudang (1612 meters), Jiugong (1543 meters), Tongbo (1140 meters), Dahong (1055 meters), and Jigong (744 meters) (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 spermatophyte species, is considered as one of the most important centers of biodiversity in China (Zheng, 1993). It is the native home to such important relic species as *Metasequoia glyptostroboides* Hu et Cheng, *Ginkgo Biloba* L, and *Davidia involucrata* Bail.

3. 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 meter intervals between 400 and 3105 meters above sea level, with the starting interval at 0 – 400 meters and the final one at 3000 – 3105 meters. 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 was described in Zhang's book, the presence of each species in every 200 meter 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.

4. Results and discussion

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

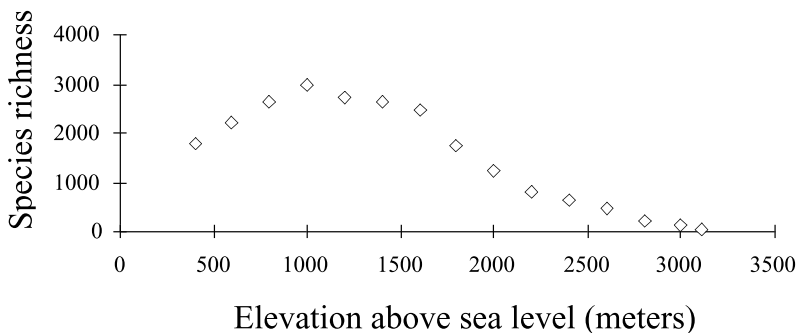


FIGURE 1

Plant species richness along elevation gradient of Hubei Province, China

which peaked at 2400-2800 meters (Wang et al., 2003), of pteridophytes in Panama with maximum at 500-1500 meters (Lellingner, 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 Vetaas 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 Hubei province.

The major decline in species richness above 1600 meters found in Hubei could be due in part to ecophysiological constraints, such as 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 meter interval used in this analyses do not represent equal area because of 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 an 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 meters 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 meters. 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 meters 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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6. References

Atlas of China. 2000. China Map Press.

Austin MP, Pausas JG, & Nicholls AO. 1996. Patterns of tree species richness in relation to environment in south-eastern New South Wales, Australia. *Australia Journal of Ecology* 21:154-164.

Austrheim G. 2002. Plant diversity patterns in semi-natural grasslands along an elevational gradient in Southern Norway. *Plant Ecology* 161:193-205

Brown J. 2001. Mammals on mountainsides: elevational patterns of diversity. *Global Ecology and Biogeography*, 10:101-109.

Colwell RK, & Lees DC. 2000. The mid-domain effect: geometric constraints on the geography of species richness. *Trends in Ecology and Evolution* 15: 70-76.

Criddle RS, Church JN, Smith BN & Hansen LD. 2003. Fundamental causes of the global patterns of species range and richness. *Russian Journal of Plant Physiology* 50: 192-199.

Curtin CG. 1995. Can montane landscapes recover from human disturbance? Long-term evidence from disturbed subalpine communities. *Biological Conservation* 74: 49-55.

Edwards ME & Armbruster WS. 1989. A tundra-steppe transition on Kathul Mountain, Alaska, USA. *Arctic Antarctic and Alpine Research* 21: 296-304.

Eriksson O. 1996. Regional dynamics of plants: Review of evidence for remnant, source-sink and metapopulations. *Oikos* 77:248-258.

Gerytnes JA & Vetaas OR. 2002. Species richness and altitude: a comparison between simulation modes and interpolated plant species richness along the Himalayan altitudinal gradient, Nepal. *American Naturalist* 159:294-304.

Heaney LR. 2001. Small mammal diversity along elevational gradients in the Philippines: an assessment of patterns and hypotheses. *Global Ecology and Biogeography*, 10:15-39.

Körner C. 1995. Alpine plant diversity: a global survey and functional interpretation. In Chapin, FS III and Körner C (eds). *Arctic and Alpine biodiversity: Patterns, Causes and Ecosystem Consequences*. Springer-Verlag. pp 45-62.

Körner C. 1998. A re-assessment of high elevation treeline positions and their explanation. *Oecologia* 115: 445-459.

- Körner C. 2000. Why are there global gradients in species richness? Mountains might hold the answer. *Trend in Ecology and Evolution* 15: 513-514.
- Lellinger, DB. 1985. *A Field Manual of the Ferns and Fern-Allies of the United States and Canada*. Washington, D.C. Smithsonian Institution Press.
- Lieberman DM. Lieberman R. Peralta. & Hartshorn GS. 1996. Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. *Journal of Ecology* 84:137-152
- Lomolino MV. 2001. Elevation gradients of species-density: historical and prospective views. *Global Ecology and Biogeography* 10:3-13.
- Mark AF. Dickinson KJM. & Hofstede RGM. 2000. Alpine vegetation, plant distribution, life forms, and environments in a humid New Zealand region: Oceanic and tropical high mountain affinities. *Arctic Antarctic and Alpine Research* 32: 240-254.
- McCoy ED1990. The distribution of insects along elevational gradients. *Oikos* 58:313-322.
- Palmer MW.1991. Patterns of species richness among North Carolina hardwood forests: tests of two hypotheses. *Journal of Vegetation Science*. 2: 361-366.
- Pauses JG. & Austin MK. 2001. Patterns of plant species richness in relation to different environments: an appraisal. *Journal of Vegetation Science* 12:153-166.
- Rahbek C. 1995. The elevation al gradient of species richness: a uniform pattern? *Ecography* 18: 200-205.
- Rahbek C. 1997. The relationship among area, elevation and regional species richness in neotropical birds. *American Naturalist*, 149:875-902.
- Richart EA. 2001. Elevational diversity gradients, biogeography, and the structure of montane mammal communities in the intermountain region of North America. *Global Ecology and Biogeography*. 10: 77-100.
- Rosenzweig ML. 1995. *Species Diversity in Space and Time*, Cambridge University Press
- Sanders NJ. Moss J. & Wagner D. 2003. Patterns of ant species richness along elevational gradients in an arid ecosystem. *Global Ecology and Biogeography*. 10: 77-100.
- Shimada A. & Wilson MW. 1985. Biological determinants of species diversity. *Journal of Biogeography*. 12:1-20.

- Tang CQ. 1997. Zonal transition of evergreen, deciduous, and coniferous forests along the altitudinal gradient on a humid subtropical mountain, Mt. Emei, Sichuan, China. *Plant Ecology* 133:63-78.
- Tilman D. & Downing JA. 1994. Biodiversity and stability in grasslands. *Nature* 367: 363-365.
- Vazquez Garcia JA. & Givnish TJ. 1998. Altitude gradients in tropical forest composition, structure, and diversity in the Sierra de Manantlan. *Journal of Ecology* 86: 999-1020.
- Vetaas OR. & Gerytnes JA. 2002. Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal. *Global Ecology and Biogeography*. 11: 291-301.
- Wang GH. Zhou GS. Yang LM. & Li ZQ. 2003. Distribution, species diversity and life form spectra of plant communities along an altitudinal gradient in the northern slopes of Qilianshan Mountains, Gansu, China. *Plant Ecology*. 165 (2):169-181.
- Whittaker RH. 1972. Evolution and the measurement of species diversity. *Taxon*. 21: 213-251.
- Woodward FI. 1988. Temperature and the distribution of plant species and vegetation. In: Long SP and Woodward FI (eds), *Plants and Temperature*. Society of Experimental Biology by The Company of Biologists Limited. Cambridge. Pp. 59-75.
- Zheng Z. 1993. Contemporary flora of spermatophyte plant species in Hubei province. Hubei Science and Technology Press.
- Zobel M. 1997. The relative role of species pools in determining plants species richness: an alternative explanation of species coexistence. *Trend in Ecology and Evolution* 12: 266-269