National Nature Reserve Cluster in Southwestern Hubei: An Important Site for Bryophyte Diversity Conservation (Postprint)

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Abstract

Southwestern Hubei Province is densely populated with four major national nature reserves—Houhe, Mulinzi, Qizimei Mountain, and Xingdou Mountain—which together form a complementary reserve group with largely similar rare flora and fauna. Meanwhile, the region' s rich geomorphic types and water-vapor resources create favorable living conditions for bryophytes. This study employs a combination of field surveys and literature review to analyze the richness and compositional characteristics of bryophytes within the national nature reserve group in southwestern Hubei, and compares their diversity with that of southeastern Chongqing and northwestern Hunan. The results show that the national nature reserve group in southwestern Hubei harbors a total of 601 bryophyte species belonging to 197 genera and 77 families, representing 19.89% and 71.46% of the total bryophyte species in China and Hubei Province, respectively. Among these, there are 27 Chinese endemic species, 15 families containing only one species, and 91 genera containing only one species. Additionally, certain similarities and complementarities exist in bryophyte species among the individual reserves within the national reserve group in southwestern Hubei, aligning with China' s biodiversity conservation principles. Furthermore, the national nature reserve group in southwestern Hubei exhibits a comprehensive bryophyte flora, with species numbers significantly higher than those in southeastern Chongqing and northwestern Hunan, which are also located in the Wuling Mountains. Therefore, the national nature reserve group in southwestern Hubei not only effectively protects large rare and endangered animals and plants, but also nurtures a rich and diverse array of bryophyte taxa, serving as an important site for bryophyte diversity conservation.

Full Text

Preamble

National Nature Reserve Group in Southwest Hubei—An Important Place for Bryophyte Diversity Conservation

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Abstract: Southwest Hubei Province hosts four national nature reserves—Houhe, Mulinzi, Qizimeishan, and Xingdoushan—that collectively form an interconnected protected area network where rare flora and fauna are similar yet complementary. The region' s diverse landforms and abundant water resources create an excellent habitat for bryophytes. This study combines field investigations with literature review to analyze bryophyte species richness and composition within this national nature reserve group, and compares bryophyte diversity with that of southeast Chongqing and northwest Hunan. The results reveal that the Southwest Hubei national nature reserve group contains 601 bryophyte species belonging to 197 genera and 77 families, representing 19.89% of China' s total bryophyte species and 71.46% of Hubei' s total. Among these, 27 species are endemic to China, 15 families are monotypic, and 91 genera contain only a single species. The bryophyte flora among the four reserves shows both similarity and complementarity, aligning with China' s biodiversity conservation principles. Moreover, the bryophyte flora in this reserve group is comprehensive, with species numbers significantly higher than those in southeast Chongqing and northwest Hunan within the same Wuling Mountain region. Therefore, the Southwest Hubei national nature reserve group not only effectively protects large rare and endangered plants and animals but also nurtures a rich and diverse bryophyte flora, making it a critical area for bryophyte diversity conservation.

Keywords: Southwest Hubei; national nature reserve group; bryophytes; conservation; biodiversity

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Introduction

Biodiversity represents the comprehensive integration of ecological complexes formed by organisms and their environments, along with associated ecological processes (Jiang, 1997). Studying biodiversity is crucial for its conservation, which generally involves in-situ and ex-situ protection methods. In-situ conservation through the establishment of nature reserves is widely recognized as the most powerful and efficient approach. However, biodiversity conservation has traditionally focused on large vascular plants, with minimal research on bryophyte diversity. In fact, bryophytes constitute the second-largest plant group after angiosperms and represent an essential component of biodiversity conservation. They provide critical ecological functions including water conservation, soil erosion prevention, and air pollution monitoring. Additionally, due to their small stature and poikilohydric nature, bryophytes exhibit distribution patterns distinct from vascular plants (Geffert et al., 2013; Möls et al., 2013) and are more strongly influenced by microenvironmental conditions. Therefore, studying bryophyte diversity in key regions is necessary to identify priority areas for conservation and enhance protection effectiveness.

Southwest Hubei represents a biodiversity hotspot and a critical region for ecological security in China (Ministry of Environmental Protection of the People' s Republic of China, 2011). The area hosts a national nature reserve group established primarily to protect rare relict plants such as *Davidia involucrata*, *Bretschneidera sinensis*, and *Cercidiphyllum japonicum*. Previous studies have documented abundant bryophytes hanging from or epiphytic on trees in these reserves, with exceptionally high species richness per unit area (Ma, 2006; Yang, 2006; Yu et al., 2019). Furthermore, Fu et al. (2019) studied the paleontology of the Qingjiang River basin in Southwest Hubei, proposing the concept of the "Qingjiang Biota" and confirming that this region was a biodiversity hotspot 518 million years ago. We therefore hypothesize that Southwest Hubei represents a core area for bryophyte diversity distribution, and that the national nature reserves in this region effectively protect bryophyte diversity. This research aims to comprehensively document the bryophyte composition across the entire reserve group, contributing to the broader understanding of biodiversity in this protected area network.

1.1 Study Area Overview

Southwest Hubei forms a protruding southwestern corner of Hubei Province, bordering eastern Chongqing and northwestern Hunan. It serves as a transitional zone where the flora of the Yunnan-Guizhou Plateau extends eastward and subtropical flora extends northward, representing a core distribution area for East Asian subtropical floristic elements. This region, known as a "natural botanical garden" and "germplasm gene bank," contains the most concentrated and diverse plant species in central China and is designated as a priority area for nature reserve development. From east to west, the area densely hosts the Mulinzi, Qizimeishan, Xingdoushan, and Houhe national nature reserves, along

with numerous smaller protected areas, forming an extensive network where wild plants are broadly similar yet complementary, and wildlife can migrate between reserves [Figure 1: see original paper]. The region' s dense mountains, deep valleys, and concurrent water-heat conditions create excellent growth environments for wildlife and have fostered a rich diversity of bryophyte species.

1.2 Data Sources and Analysis

This study employed a combination of field investigations and literature analysis to examine bryophyte resources in the Southwest Hubei national nature reserve group. Between 2016 and 2019, we conducted field surveys of bryophytes in Mulinzi National Nature Reserve (109°59' 30 -110°17' 58 E, 29°55' 59 -30°10' 47 N), Qizimeishan National Nature Reserve (109°38 30 -109°47 00 E, 29°39 30 - 30°05 15 N), and Houhe National Nature Reserve (110°29 25 -110°40 45 E, 30°02 45 -30°08 40 N). Species identification was performed using reference works including *Moss Flora of China* (Li, 2000, 2006; Wu, 2002, 2011; Hu & Wang, 2005; Gao, 2003, 2008) and *Species Catalogue of China* (Jia & He, 2013), with some results published in the *Journal of Zhejiang A&F University* (Yu et al., 2019). We also compiled published bryophyte data for Houhe and Xingdoushan reserves (108°57 -109°27 E, 29°57 -30°10 N; 108°31 -108°48 E, 30°04 -30°14 N) from Peng (2003), Wang (2006), and Ma (2006). All bryophyte scientific names, synonyms, and classification systems were standardized according to Jia & He (2013), and threatened bryophytes were identified based on the *Threatened Species List of China' s Higher Plants* (Qin et al., 2017).

We used Origin 2018 (OriginLab Corp, USA) to generate Venn diagrams and calculate similarity among the four reserves. The Sørensen similarity coefficient was computed as:

Sørensen similarity coefficient = 2c / (a + b) × 100%

where a represents the number of families, genera, or species in area A; b represents the number in area B; and c represents the number of families, genera, or species shared between areas A and B (Zhang et al., 2002; Zhang & Zhang, 1998).

Results

2.1 Species Richness and Similarity

The Southwest Hubei reserve group contains 601 bryophyte species belonging to 197 genera and 77 families, representing 81.05%, 74.06%, and 71.46% of Hubei' s total bryophyte families, genera, and species respectively (Liu et al., 1998; Tian et al., 1998; Tian & Liu, 1998; Liu et al., 2001; Peng, 2003; Wu et al., 2003; Yao & Hong, 2003; Ma et al., 2005, 2006; Wang, 2006; Xiang et al., 2006; Hu et al., 2007; Hong, 2007, 2008; Li et al., 2011; Fan et al., 2017; Yu et al., 2018), and 51.33%, 33.33%, and 19.89% of China' s total bryophyte families, genera, and species (Jia & He, 2013). Specifically, Mulinzi National Nature Reserve hosts 292 species in 121 genera and 66 families; Qizimeishan Reserve has 285 species

in 136 genera and 70 families; Houhe Reserve contains 194 species in 91 genera and 36 families; and Xingdoushan Reserve comprises 226 species in 88 genera and 32 families [Figure 2: see original paper].

Further analysis revealed 30 species shared among all four reserves, mostly common species such as *Leucobryum glaucum*, *Pogonatum inflexum*, and *Fissidens dubius*. Among pairwise comparisons, Qizimeishan and Mulinzi reserves shared the most species (166), accounting for 27.62% of the total species in the reserve group, while Houhe and Qizimeishan shared the fewest (63), representing 10.48%. Each reserve also harbored numerous unique species: Houhe had 77 unique species (12.81% of the total), including *Dicranella cerviculata*, *Trachycystis flagellaris*, *Duthiella wallichii*, and *Lejeunea punctiformis*, primarily above 1,200 m elevation; Mulinzi had 80 unique species (13.31%), including *Fissidens hyalinus*, *Pleuroziopsis ruthenica*, *Pohlia cruda*, and *Trichocolea sacculata*, mainly between 1,000–1,500 m; Qizimeishan had 88 unique species (14.64%), including *Weisiopsis plicata*, *Amblystegium serpens*, *Plagiochila arbuscula*, and *Notoscyphus lutescens*, primarily above 1,000 m; and Xingdoushan had 88 unique species (14.64%), including *Dicranum mayrii*, *Ctenidium capillifolium*, *Porella japonica*, and *Frullania muscicola*, mainly between 600–1,200 m. These findings demonstrate both similarity and strong complementarity in bryophyte species among the reserves.

Similarity coefficients calculated using the Sørensen formula revealed that Mulinzi and Qizimeishan reserves had the highest similarity at both genus and species levels and shared the most families. Houhe and Xingdoushan shared the fewest families, Houhe and Mulinzi had the lowest genus similarity, and Houhe and Qizimeishan had the lowest species similarity .

2.2 Composition Characteristics

At the family level, 14 dominant families (each with >15 species) comprised 351 species, representing 58.5% of the total bryophyte flora in the region. At the genus level, 12 dominant genera (each with >10 species) contained 174 species, accounting for 29% of the total. Monotypic families numbered 15 (19.48% of total families), while monotypic genera numbered 91 (46.19% of total genera) [Figure 3: see original paper].

2.3 Chinese Endemic Species

The reserve group contains 26 bryophyte species endemic to China (0.08% of China' s total bryophytes) . Mulinzi Reserve hosts 11 endemic species, Qizimeishan Reserve has 13, Houhe Reserve contains 12, and Xingdoushan Reserve has 9.

2.4 Threatened Species

Two threatened bryophyte species occur in the reserve group: *Hypnum densirameum* and *Racopilum convolutaceum*. *Hypnum densirameum* is primarily

distributed in Mulinzi National Nature Reserve, growing along forest trails at approximately 1,150 m elevation. *Racopilum convolutaceum* occurs mainly in Qizimeishan National Nature Reserve, inhabiting rocky slopes around 840 m elevation. Although other species face lower threat levels, they are still impacted by habitat fragmentation and human exploitation, such as *Sphagnum palustre* and *Leucobryum glaucum*.

2.5 Comparison with Southeast Chongqing and Northwest Hunan

Southwest Hubei borders southeast Chongqing and northwest Hunan (Xiong, 2007). All three regions lie in the transitional zone between China' s second and third topographic steps, within the Wuling Mountains, and share similar geographic environments and climates. Comparative analysis shows that Southwest Hubei far exceeds the other two regions in bryophyte species richness, demonstrating clear advantages at family, genus, and species levels [Figure 4: see original paper]. This confirms Southwest Hubei as a core area for bryophyte diversity distribution in the Wuling Mountains. Using the family:genus:species ratio as an indicator of species differentiation (higher ratios indicate greater differentiation) (Liu et al., 2016), we found ratios of 1:2.53:7.72 for Southwest Hubei, 1:2.56:7.87 for southeast Chongqing, and 1:2.38:5.95 for northwest Hunan. Southwest Hubei and southeast Chongqing exhibit "few families, many species," indicating relatively young and newly derived flora, while northwest Hunan shows "many families, few species," suggesting more ancient and conservative characteristics.

Discussion

Based on recent field survey data and literature, our analysis of bryophyte species richness and compositional differences in the Southwest Hubei reserve group reveals that its bryophyte species represent 19.89% of China' s total and 71.46% of Hubei' s total. Despite covering only 12.91% of Hubei' s area, the region harbors over two-thirds of the province' s bryophyte species, surpassing the Shennongjia Forest District in richness and becoming the most bryophyte-diverse area in the province (Liu et al., 1999). The reserve group' s bryophyte composition includes 14 dominant families (351 species, 58.5% of the regional total) and 12 dominant genera (174 species, 29% of the total). However, numerous monotypic families and genera, along with a substantial number of Chinese endemic species, demonstrate the typical and unique nature of the region' s bryophyte flora.

Sørensen similarity comparisons among the four reserves within the group show relatively close coefficients at family, genus, and species levels, reflecting their similar climatic environments and geographic locations. Nevertheless, distinct differences exist: Mulinzi and Qizimeishan reserves exhibit the highest similarity, likely due to their proximity and continuous subalpine corridors that facilitate species exchange. In contrast, Houhe and Mulinzi reserves show the lowest genus similarity, while Houhe and Qizimeishan have the lowest species

similarity. Interestingly, despite being the most distant pair, Houhe and Xingdoushan reserves show relatively high species similarity. Further investigation reveals their mean annual temperatures are very similar (13.1°C for Houhe, 12.7°C for Xingdoushan), and both feature vegetation dominated by Tertiary relict rare and endangered plant communities with similar dominant species (Huang et al., 2016; Wang et al., 2017). Additionally, both reserves have steep slopes. Research indicates that temperature, vegetation type, and slope can significantly alter bryophyte community structure and diversity (Woodward, 1987; Tian et al., 2013; Cecilia et al., 2020). Therefore, the high species similarity between Houhe and Xingdoushan may be attributed to these environmental factors. Overall, the four reserves share regional climatic characteristics while maintaining microenvironmental and microclimatic differences, creating diverse habitats suitable for various bryophyte types.

Southwest Hubei, southeast Chongqing, and northwest Hunan are geographically proximate and constitute a modern center of bryophyte abundance in China (Xiong, 2007). However, Southwest Hubei shows significantly higher bryophyte species richness, confirming its status as a core area for bryophyte diversity in the Wuling Mountains. The comparison of family:genus:species differentiation ratios reveals that Southwest Hubei and southeast Chongqing exhibit relatively young and newly derived characteristics, while northwest Hunan appears more ancient and conservative. This may result from intense geological activity in the former two regions (Zhou et al., 2010; Zhao et al., 2011), as they are closer to the Hengduan Mountains and thus more affected by geological changes.

In conclusion, although the Southwest Hubei reserves were originally established to protect north subtropical montane forest ecosystems and rare vascular plants such as *Davidia involucrata*, *Bretschneidera sinensis*, and *Cercidiphyllum japonicum*, research shows that protecting 90% of vascular plants in a given area simultaneously protects only 65% of bryophytes (Pharo et al., 2000). The rich landforms and microclimates of the Southwest Hubei reserve group, however, are highly suitable for bryophyte growth. Our results confirm the region' s exceptionally high bryophyte diversity, far exceeding that of adjacent southeast Chongqing and northwest Hunan. Moreover, the similarity and complementarity of bryophyte species among reserves, along with pronounced unique species in each reserve, demonstrate that the reserve group network effectively protects bryophyte diversity while facilitating species exchange, aligning well with China' s biodiversity conservation principles. Therefore, this reserve group not only provides excellent habitats for wildlife but also nurtures a rich diversity of bryophyte species, serving as a critical area for bryophyte diversity conservation.

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