

Composition Analysis of Lycophytes and Ferns in Yunzhongshan Nature Reserve, Fujian Province

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Abstract [Objectives] To analyze the composition of lycophytes and ferns in Yunzhongshan Nature Reserve, Fujian Province. [Methods] This study examined the composition of lycophytes and ferns in Yunzhongshan Nature Reserve through field investigations and specimen identification, supplemented by a review of relevant literature. [Results] A total of 84 species of lycophytes and ferns were identified, encompassing 55 genera and 29 families. This included 14 species of lycophytes distributed across 8 genera and 3 families, as well as 70 species of ferns belonging to 47 genera and 26 families. Polypodiaceae and *Selaginella* were the dominant family and genus, respectively, while oligospecific families and monotypic genera were significant components of lycophytes and ferns in the region. The distribution types of these families were primarily cosmopolitan and tropical. The Germline differentiation degree (SD) was 3.34, and the proportion of rare or endangered species among lycophytes and ferns was 8.33%. [Conclusions] Yunzhongshan Nature Reserve possesses a diverse array of lycophyte and fern species. This study offers valuable scientific insights that can inform efforts related to the conservation of biodiversity, resource utilization and development, species introduction, and system evolution of lycophytes and ferns within the reserve.

Key words Nature reserve, Lycophytes, Ferns, Composition

1 Introduction

Ferns are the most primitive vascular plants and are extensively distributed across temperate and tropical forest ecosystems worldwide^[1]. Ferns are significant components of forest ecosystems, playing a crucial role in the growth and development of forests. Additionally, they possess various values, including ornamental and medicinal uses. Ferns can also function as sensitive indicator species, reflecting local environmental conditions. Ferns possess an ancient origin and encompass a diverse array of species. Lycophytes and ferns in China constitute approximately 1/5 of the total number of species worldwide^[2]. In recent years, the advancement of biodiversity surveys has facilitated the progressive implementation of research on the diversity of lycophytes and ferns across various regions^[3–5]. Investigating lycophytes and ferns at different regional scales enhances our understanding of the origin and systematic evolutionary processes of plant groups within these regions, thereby contributing to the conservation of plant diversity, particularly that of rare and endangered species.

Anxi Yunzhongshan Provincial Nature Reserve is a designated provincial nature reserve located in Fujian Province. Its primary purpose is to conserve the natural ecosystem constituted by the original forest vegetation and the habitats at the headwaters of the tributaries of the Jinjiang and Jiulong Rivers. The reserve also serves to protect numerous rare and endangered animal and plant

species. It is recognized as "a valuable genetic repository for species in southeastern China"^[6]. Currently, research has been conducted on the resource types and flora of seed plants, Orchidaceae, and medicinal plants within the Yunzhongshan Nature Reserve^[7–10]. Additionally, analyses of the community characteristics of natural forests of Qinggang in Fujian Province and the vertical distribution characteristics of vegetation resources in the reserve have been performed^[11–12]. However, studies focusing on the flora of lycophytes and ferns remain scarce.

This study focuses on the lycophytes and ferns within the Anxi Yunzhongshan Provincial Nature Reserve. Utilizing field investigations, statistical analyses, and a comprehensive review of relevant literature, it compiles a checklist of lycophyte and fern species present in the reserve. Furthermore, the study examines their structural composition, dominant taxa, and identifies rare and endangered species. The objective is to provide a scientific basis for research on biodiversity conservation, resource utilization, species introduction, and system evolution of lycophytes and ferns in this reserve.

2 Materials and methods

2.1 Overview of the study area Anxi Yunzhongshan Provincial Nature Reserve (117°35'39"–117°44'45" E, 25°16'19"–25°21'00" N) is situated in the northwest of Anxi County, Quanzhou City. It encompasses a total area of 4 163.6 hm², with elevations ranging from 270 to 1 600 m above sea level. The region experiences a warm and humid climate, and its predominant soil types are red soil and yellow-red soil. The soil profile is deep, and the area is characterized by numerous streams. This reserve lies within the transitional zone between the southern subtropical and middle subtropical climatic regions. The favorable natural conditions support a rich diversity of wild fauna and flora.

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2.2 Research methods The line transect method, in conjunction with interviews, was employed to carry out on-site investigations of lycophytes and ferns within the reserve. During these investigations, records, photographs, and specimens were collected. Identification of lycophytes and ferns was conducted by consulting relevant literature, including the *Flora of China*, the *China Plant Image Database*, the *Flora of Fujian*, *etc.* The classification system utilized in the *Flora of China* was adopted for the taxonomic classification of lycophytes and ferns.

2.3 Statistical analysis Referring to the classification method proposed by Yan Yuehong *et al.*^[13], a statistical analysis was performed on the distribution area types of lycophyte and fern families, genera, and species within the reserve. The germline differentiation degree (SD) of lycophytes and ferns in the Yunzhongshan Nature Reserve was compared with that of eight other reserves, namely Tingjiangyuan, Meihushan, and Liangyeshan in Fujian Province; Ganjiangyuan and Matoushan in Jiangxi Province; Wuzhishan in Hainan Province; Yunkaishan in Guangdong Province; and Mayanghe in Guizhou Province, based on the SD values calculated by Zhang Xiuhua^[14].

$$SD = \frac{n_2}{n_1} + \frac{n_3}{n_2}$$

In the formula, n_1 , n_2 , and n_3 denote the number of families, genera, and species within the flora, respectively.

3 Results and analysis

3.1 Composition analysis The statistical analysis of lycophytes and ferns within the reserve revealed the presence of 84 species, encompassing 55 genera and 29 families. These figures represented 76.32%, 31.07%, and 3.72% of the total families, genera, and species of lycophytes and ferns in China, respectively (Table 1). Furthermore, they corresponded to 90.63%, 54.46%, and 20.69% of the total families, genera, and species of these plants in Fujian Province, respectively. The region comprised a total of 3 families, 8 genera, and 14 species of lycophytes, representing 10.34%, 14.55%, and 16.67% of the total families, genera, and species of lycophytes and ferns in the region, respectively. These lycophytes corresponded to 100%, 66.67%, and 8.48% of the families (3), genera (12), and species (165) of lycophytes recorded in China. Additionally, the region contained 70 species of ferns distributed across 46 genera and 26 families, accounting for 89.66%, 85.45%, and 83.33% of the total families, genera, and species of lycophytes and ferns in the region, respectively.

3.2 Dominant families and genera The statistical analysis of the dominant families and genera of lycophytes and ferns within the reserve (Tables 2–3) revealed that, at the family level, oligospecific families represented the primary family groups, followed by monotypic families. Furthermore, monotypic and oligospecific families collectively accounted for 79.31%, 61.82%, and 55.95% of the total number of families, genera, and species, respectively, in this region. At the genus level, monotypic genera were predominant among lycophytes and ferns, followed by oligospecific genera.

Table 1 Composition of lycophytes and ferns in Yunzhongshan Nature Reserve

No.	Family	Number of genera	Number of species
1	Lycopodiaceae	5	5
2	Selaginellaceae	1	7
3	Huperziaceae	2	2
4	Equisetaceae	1	1
5	Marattiaceae	1	1
6	Osmundaceae	1	2
7	Lygodiaceae	1	1
8	Plagiogyriaceae	1	1
9	Gleicheniaceae	2	4
10	Hymenophyllaceae	2	1
11	Monachosoraceae	1	1
12	Dennstaedtiaceae	2	2
13	Cibotiaceae	1	1
14	Lindsaeaceae	3	4
15	Davalliaceae	1	2
16	Nephrolepidaceae	1	1
17	Pteridaceae	2	6
18	Adiantaceae	1	3
19	Hemionitidaceae	1	2
20	Sinopteridaceae	1	1
21	Athyriaceae	2	3
22	Aspleniaceae	1	3
23	Thelypteridaceae	4	4
24	Blechnaceae	3	5
25	Cyatheaceae	1	2
26	Dryopteridaceae	2	3
27	Polypodiaceae	8	12
28	Drynariaceae	1	2
29	Vittariaceae	1	1
30	Botrychiaceae	1	1
Total	29	55	84

Among the lycophytes, the Selaginellaceae family exhibited the greatest species diversity, comprising 1 genus and 7 species, thereby representing the predominant group of lycophytes in this region. In contrast, the Lycopodiaceae family included 5 genera, each represented by a single species. The Polypodiaceae family was the largest among the ferns in this region, followed by the Pteridaceae and Blechnaceae families, which accounted for 10.34%, 23.63%, and 27.38% of the total number of families, genera, and species, respectively. The genus *Pteris* comprised 5 species, representing 2.13% of the total fern genera and 7.14% of the total fern species, thereby constituting the dominant genus in this region. Among the ferns, monotypic genera were the most abundant, encompassing 32 genera and 32 species, including *Equisetum*, *Angiopteris*, and *Lygodium*, which accounted for 68.08% of the total genera and 45.71% of the total species of ferns, respectively.

Table 2 Statistics of the families of lycophytes and ferns in Yunzhongshan Nature Reserve

Type	Family		Genus		Species	
	Number	Proportion//%	Number	Proportion//%	Number	Proportion//%
Monotypic family (1 species)	12	41.38	12	21.82	11	13.10
Oligospecific family (2–4 species)	12	41.38	24	43.64	38	45.24
Medium family (5–9 species)	4	13.79	11	20.00	23	27.38
Large family (≥10 species)	1	3.45	8	14.55	12	14.29
Total	29	100	55	100	84	100

Table 3 Statistics of the genera of lycophytes and ferns in Yunzhongshan Nature Reserve

Type	Genus		Species	
	Number	Proportion//%	Number	Proportion//%
Monotypic genus (1 species)	39	70.91	39	46.43
Oligospecific genus (2–4 species)	14	25.45	33	39.29
Small genus (5–9 species)	2	3.64	12	14.28
Total	55	100	84	100

3.3 Distribution of rare and endangered lycophytes and ferns

According to the *List of National Key Protected Wild Plants* issued in 2021, 84 species of lycophytes and ferns are present within the reserve. Among these, the second-class national key protected wild plants include *Cibotium barometz*, *Angiopteris foksienis*, *Huperzia serrata*, *Phlegmariurus mingcheensis*, *Brainea insignis*, *Alsophila spinulosa*, and *Gymnosphaera podophylla*, which collectively constitute 8.33% of the total species.

3.4 Comparison with other reserves

3.4.1 Flora comparison. The analysis of the flora division of lycophytes and ferns at the family level within the reserve revealed that the 29 plant families can be categorized into five distribution types. The predominant types were cosmopolitan and tropical distributions, with only one family, Botrychiaceae, exhibiting a temperate distribution. Notably, the cosmopolitan distribution encompassed 13 families, including Lycopodiaceae, Selaginellaceae, Equisetaceae, and Osmundaceae.

Families with a tropical distribution constituted 93.75% of the total number of families, excluding those with a cosmopolitan distribution. Among these, the pan-tropical distribution encompassed 13 families, including Huperziaceae, Marattiaceae, and

Lygodiaceae. Families characteristic of the Old World Tropic included Davalliaceae and Blechnaceae. Notably, the Plagiogyriaceae family was the sole family distributed across both tropical Asia and tropical America.

A comparative analysis of the lycophyte and fern flora with the Tingjiangyuan Nature Reserve, Fujian Province, revealed that both groups were predominantly characterized by cosmopolitan and tropical distribution types. However, the proportion of families exhibiting a tropical distribution in the Yunzhongshan Nature Reserve was slightly lower than that observed in the Tingjiangyuan Nature Reserve, where tropical families accounted for 100% of the total number of families^[14]. Additionally, the Yunzhongshan Reserve contained one family with a temperate distribution type, whereas no temperate distribution types were identified in the Tingjiangyuan Reserve.

3.4.2 Germline differentiation degree (SD). The analysis of SD within the reserve, compared to other reserves, revealed a value of 3.34, representing the lowest among the eight reserves examined. This value was approximately 0.53 times that of Wuzhishan in Hainan and comparable to that of Tingjiangyuan in Fujian (Table 4).

Table 4 Germline differentiation degree between Yunzhongshan Nature Reserve and other reserves

Region	Geographical coordinate	Elevation//m	SD
Yunzhongshan, Fujian	117°35′–117°44′ E, 25°16′–25°21′ N	270–1 600	3.34
Tingjiangyuan, Fujian	116°02′–116°30′ E, 25°35′–26°02′ N	500–1 248	4.75
Meihuashan, Fujian	116°45′–116°57′ E, 25°15′–26°35′ N	375–1 811	5.19
Liangyeshan, Fujian	116°00′–116°15′ E, 25°04′–26°20′ N	272–1 538	4.69
Ganjiangyuan, Jiangxi	116°15′–116°29′ E, 25°56′–26°07′ N	500–1 200	5.64
Matoushan, Jiangxi	119°09′–117°18′ E, 27°04′–27°53′ N	500–1 300	5.72
Wuzhishan, Hainan	109°39′–109°47′ E, 18°49′–18°58′ N	200–1 867	6.25
Yunkaishan, Guangdong	111°08′–111°28′ E, 22°14′–22°24′ N	600–1 704	5.91
Mayanghe, Guizhou	108°03′–108°19′ E, 28°37′–28°54′ N	280–1 441	5.77

NOTE Except for the SD of Yunzhongshan in Fujian Province, the SD of the other eight reserves were all obtained through the analysis of the geographical characteristics of lycophytes and ferns in Tingjiangyuan, Fujian Province^[14].

4 Discussion

The Yunzhongshan Provincial Nature Reserve harbors 84 species of

lycophytes and ferns, which are distributed across 55 genera and 29 families. Specifically, the reserve contains 14 species of lyco-

phytes belonging to 8 genera and 3 families, as well as 70 species of ferns representing 47 genera and 26 families. These findings indicate that the area possesses a rich diversity of lycophyte and fern resources. In this region, the family Polypodiaceae is predominant, with the genus *Selaginella* being the most prevalent genus. Monotypic and oligospecific families represent a significant portion of the lycophytes and ferns present, constituting the primary contributors to the diversity of families and genera in this region. This pattern suggests a low degree of differentiation within the families and genera of lycophytes and ferns, indicating relatively simple structural characteristics. This conclusion is further supported by the observed SD in the region.

The phylogenetic analysis of plants suggests that lycophytes represent the most primitive lineage. Ferns are believed to have originated either from ancient basal groups, such as the Equisetaceae family, or from more derived mid-evolutionary groups, including the Lindsaeaceae and Dennstaedtiaceae families, as well as from the Polypodiaceae family, which occupies a more advanced position in systematic evolution. The analysis of the composition of lycophytes and ferns within the reserve reveals the presence of groups at various developmental stages, including Equisetaceae, Lindsaeaceae, and Polypodiaceae. This finding suggests that the ferns in this region possess an ancient origin and exhibit coherent phylogenetic relationships. These results are consistent with previous studies conducted on lycophytes and ferns in the Tingjiangyuan Nature Reserve^[14].

Within the reserve, lycophytes and ferns exhibit five distinct distribution types. In addition to the cosmopolitan distribution, tropical and temperate distributions are also present; however, the cosmopolitan and tropical distributions predominate. This distribution pattern suggests a complex plant geographical composition that aligns with the subtropical climatic characteristics of the region. These findings are consistent with analyses of fern flora components conducted in adjacent reserves, including Tingjiangyuan, Meihuashan, and Liangyeshan, as reported by previous scholars^[14].

The SD within a flora serves as an indicator for assessing species differentiation and constitutes a critical criterion for evaluating species richness. A comparison of SD between the Yunzhongshan Reserve and other reserves reveals that the SD of Yunzhongshan is lower than that of other reserves and exhibits only a slight difference from that of the Tingjiangyuan Reserve. This observation may be attributed to the similarity in latitude, elevation, and climatic conditions between the two reserves, as well as their relatively minor habitat differences, with both reserves situated within subtropical regions.

The analysis of the components of rare and endangered lycophytes and ferns within the reserve reveals that the ecological environment is relatively well-preserved, offering a favorable habitat

for the growth of these plants, particularly those belonging to the Cyatheaceae family. Notably, rare and endangered taxa such as members of the Cyatheaceae family and *B. insignis* possess ancient evolutionary origins. The observed increase in the populations of these species within the reserve holds significant value for research on plant phylogeny and the study of ancient flora.

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