Postprint of the Elevational Distribution Pattern of Species Diversity in the Tropical Natural Forest of Diaoluo Mountain

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Abstract

Elevational gradient is a key factor influencing patterns of species diversity. To investigate the elevational distribution patterns of species diversity in the tropical natural forests of Diaoluo Mountain, vegetation surveys were conducted in six tropical natural forest sample plots within an elevational range of 245–1,130 m, analyzing the variation patterns of species diversity and community characteristics along the elevational gradient from the aspects of community species composition, species diversity, floristic composition, and leaf traits. The results showed: (1) With increasing elevation, decreasing temperature, increasing humidity, and reduced anthropogenic disturbance, species composition and the Margalef, Shannon-Wiener, Simpson, and Pielou diversity indices all exhibited a hump-shaped pattern; mid-elevation communities had the most suitable hydrothermal conditions, moderate anthropogenic disturbance, and the highest alpha diversity. (2) With increasing elevation, the proportion of importance values of dominant species exhibited a U-shaped pattern, with obvious replacement phenomena among dominant species, and mid-elevation communities showed transitional characteristics between lowland rainforest and montane rainforest. (3) Sørensen community similarity between communities showed a significant negative correlation with elevational difference ($P < 0.05$). (4) The floristic composition was absolutely dominated by tropical distribution, primarily tropical Asian (Indo-Malaysian) distribution; the proportion of tropical distribution showed an extremely significant negative correlation with elevation ($P < 0.01$), while the proportion of temperate distribution showed an extremely significant positive correlation with elevation ($P < 0.01$). (5) Leaf traits exhibited prominent tropical characteristics, dominated by medium-sized leaves, simple leaves, leathery leaves, and entire leaves; the proportions of small leaves and simple leaves showed extremely significant positive correlations with elevation ($P < 0.01$), while the proportions of leathery leaves and non-entire leaves showed no significant correlation with elevation ($P > 0.05$). In summary, substantial

differences in hydrothermal conditions and anthropogenic disturbance levels between low-elevation and high-elevation communities in Diaoluo Mountain led to differences in species distribution and community characteristics, reflecting the adaptation of tropical plants to their habitat conditions.

Full Text

Altitude Distribution Pattern of Species Diversity in Tropical Natural Forest in Diaoluo Mountain

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Abstract

Altitude gradient is a key factor influencing species diversity patterns. To explore the altitudinal distribution pattern of species diversity in the tropical natural forests of Diaoluo Mountain, we conducted vegetation surveys in six tropical natural forest plots spanning elevations from 245 m to 1,130 m. We analyzed changes in species diversity and community characteristics along the elevational gradient, examining species composition, diversity indices, floristic composition, and leaf traits. The results showed: (1) With increasing elevation, temperature decreased, humidity increased, and human disturbance decreased. Species composition and diversity indices (Margalef, Shannon-Wiener, Simpson, and Pielou) exhibited a hump-shaped pattern, peaking at mid-elevations where hydrothermal conditions were optimal and human disturbance moderate, resulting in the highest α species diversity. (2) The proportion of important values of dominant species showed a U-shaped pattern with elevation, with obvious species replacement. Mid-altitude communities exhibited transitional characteristics between lowland and montane rainforests. (3) Sørensen community similarity between plots was significantly negatively correlated with altitudinal difference ($P < 0.05$). (4) Floristic composition was overwhelmingly dominated by tropical elements, primarily tropical Asian (Indo-Malaysian) distribution. The proportion of tropical distribution was significantly negatively correlated with elevation ($P < 0.01$), while temperate distribution was significantly positively correlated with elevation ($P < 0.01$). (5) Leaf traits were characterized by mesophyll, simple, leathery, and entire leaves, typical of tropical regions. The proportions of microphyll leaves and simple leaves were significantly positively correlated with elevation ($P < 0.01$), while correlations for leathery and non-entire leaves were not significant ($P > 0.05$).

In conclusion, significant differences in hydrothermal conditions and human disturbance between low- and high-elevation communities in Diaoluo Mountain lead to distinct patterns in species distribution and community characteristics, reflecting the adaptation of tropical vegetation to environmental conditions.

Keywords: altitude gradient, tropical natural forest, species composition, species diversity, flora, leaf characteristics

Introduction

Species diversity is crucial for reflecting community richness, structural complexity, and ecosystem stability (Legendre et al., 2009; Ghaley & Porter, 2014). Plant community composition varies under different habitat conditions, and altitude gradient alters environmental factors such as light, temperature, and humidity (Gaston, 2000; Simsim et al., 2015), even affecting the degree of human disturbance to forests, making it one of the key factors influencing species diversity patterns (Brown, 2001). Generally, temperature decreases while humidity increases with elevation, and human disturbance declines at higher altitudes (Long, 2016). Previous studies have categorized elevational patterns of species diversity into five types (He & Chen, 1997): monotonic decrease (negative correlation with elevation), monotonic increase (positive correlation), hump-shaped (increase then decrease), U-shaped (decrease then increase), and no significant correlation. In humid regions with minimal human disturbance, temperature is the primary factor controlling vertical species distribution, and diversity decreases with elevation (Tang & Fang, 2004). In arid regions, although temperature decreases with elevation, increased rainfall benefits species diversity, while harsh conditions at mountain tops (cold temperatures and strong winds) reduce diversity, creating a hump-shaped pattern (Long, 2016). Thus, species distribution varies along mountain slopes due to multiple factors including hydrothermal conditions, light, community characteristics, and external disturbance (Long, 2016), with different habitat conditions producing distinct floristic compositions and community appearances.

Temperature changes cause floristic composition to shift from tropical to temperate elements with increasing elevation (Zhu, 2008), while reduced human disturbance leads to increased Chinese endemic distribution at high elevations (Su, 2007) and more complex floristic geographical components (Wu et al., 2021). Studies of *Quercus aquifolioides* communities show that leaf traits change with elevation, with increased microphyll proportion and decreased papery leaf proportion (Liu et al., 2013), reflecting plant adaptation to habitats (Lü, 2012). Therefore, investigating elevational patterns of species diversity and community characteristics is essential for revealing relationships between trees and altitude.

Hainan Diaoluoshan National Forest Park is an important tropical forest region in China, featuring the most developed tropical forests in China' s tropical zone that closely approach equatorial rainforests (Jiang, 2006). Vegetation types including tropical lowland rainforest and tropical montane rainforest are distributed along the elevational gradient. Previous research on Diaoluoshan' s tropical natural forests has focused on species diversity, floristic composition, and community characteristics (An et al., 1999; Ding et al., 2002; Wang et al., 2015; Han et al., 2019), but primarily based on single vegetation types. The patterns of species diversity and community characteristics along the complete elevational gradient remain understudied. Using six permanent plots from tropical lowland to montane rainforest, this study addresses: (1) how species diversity changes with elevation, (2) how elevation affects floristic composition, and (3) how elevation influences leaf traits, providing a basis for biodiversity conservation and ecological management of tropical forests at different elevations.

1. Materials and Methods

1.1 Study Area Overview

Diaoluoshan National Forest Park is located in southeastern Hainan Island (109°41 38 -110°4 46 E, 18°40 45 -18°46 13 N). The region has an East Asian oceanic tropical monsoon climate with a mean annual temperature of 20.8°C and abundant rainfall of 1,800–2,800 mm, showing distinct wet and dry seasons. The mountain exhibits pronounced vertical climate variation, with temperature decreasing by 0.6°C per 100 m elevation gain and distinct cold periods above 500 m (Jiang, 2006). Rainfall and relative humidity increase with elevation, accompanied by more frequent fog. Vegetation types transition from tropical lowland rainforest to tropical montane rainforest, summit evergreen dwarf forest, and scrub along the elevational gradient (Ding et al., 2002). Parent rocks are granite and diorite, with yellow latosol below 300 m and mountain yellow soil above 300 m (Wang et al., 1999). The area is rich in mountain springs and water resources, with favorable natural conditions of light, heat, and moisture that nurture abundant plant resources.

1.2 Plot Setup and Survey

To investigate species diversity and community characteristics of tropical natural forests at different elevations in Diaoluoshan, we established six permanent plots (Plot 1-Plot 6) distributed from 245 m to 1,130 m elevation, representing distinct altitudinal levels with complete and well-developed community structures. Plot details are shown in Table 1. Plots 1 and 2 (245–475 m) represent tropical lowland rainforest; Plots 3 and 4 (555–665 m) represent transitional communities between lowland and montane rainforest; Plots 5 and 6 (940–1,130 m) represent tropical montane rainforest.

Each plot covered 2,500 m^2 (50 m $\times$ 50 m), totaling 1.5 ha. Using the southwest corner as the origin, we divided each plot into five 50 m $\times$ 10 m subplots using the adjacent grid method, then further divided these into 10 m $\times$ 10 m quadrats, yielding 150 quadrats total. We conducted a complete census of all woody plants with diameter at breast height (DBH) $\geq$ 3 cm, tagging each individual and recording DBH, height, and crown width. Species identification followed *Checklist of Plant Species in Hainan* and *Flora of China* (Yang, 2016).

Table 1. Plot settings

Plot	Altitude (m)	Coordinate	Aspect
1	245$±5|18°40′45″N, 109°55′13″E|East||2|475±5|18°46′13″N, 109°56′09″E|Southwest||3|555±5|1	18°4?′5?″ N, 109°51 40 E	Southwest

1.3 Important Value Calculation

Important value (IV) was calculated as:
IV = (relative density + relative frequency + relative dominance) / 3

Dominant species in each plot were determined based on IV (Long, 2016).

1.4 Species Diversity Indices

1.4.1 α Diversity We measured α diversity using Margalef richness index, Shannon-Wiener diversity index, Simpson diversity index, and Pielou evenness index (Lakhani & Magurran, 1989).

Margalef richness index:

$$D_{Mg} = \frac{S-1}{\ln N}$$

Shannon-Wiener diversity index:

$$H' = -\sum_{i=1}^{S} P_i \ln P_i$$

Simpson diversity index:

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

Pielou evenness index:

$$J = \frac{H'}{\ln S}$$

Where S is the number of species, N is the total number of individuals, and P is the relative abundance of species i ($P = N / N$).

1.4.2 β Diversity β diversity was measured using Sørensen community similarity (Long, 2016):

Sørensen similarity index:

$$C_s = \frac{2c}{a+b}$$

Where a and b are the numbers of species in two plots, and c is the number of shared species.

1.5 Community Flora Analysis

Following Wu et al.' s (2006) classification system for areal types of seed plant genera, we analyzed the floristic composition of tropical natural forest plots at different elevations.

1.6 Community Appearance Characteristics Analysis

Based on Raunkiaer' s leaf size classification system and Paijimans' s leaf texture system (Wang, 1987), we analyzed leaf traits of communities at different elevations. Leaves were classified by size into six categories: leptophyll, nanophyll, microphyll, mesophyll, macrophyll, and megaphyll; by type into simple and compound; by texture into leathery, papery, and membranous; and by margin into entire and non-entire.

1.7 Data Processing

Data analysis and graphing were performed using Microsoft Excel 2021 and Origin 2021. Pearson correlation coefficients and Spearman rank correlation coefficients were calculated using Origin 2021 to analyze correlations between altitudinal difference and Sørensen similarity, elevation and floristic composition, and elevation and leaf traits.

2. Results and Analysis

2.1 Species Composition

Survey results (Table 2) showed rich species composition in Diaoluoshan' s tropical natural forests. With increasing elevation, the numbers of families, genera, and species exhibited a hump-shaped pattern, peaking in mid-altitude Plots 3 and 4, which represent the transition between lowland and montane rainforest. Monotypic families and genera also showed a hump-shaped pattern, with lowland rainforest communities having more monotypic families and genera than montane rainforest. All communities had high proportions of monotypic genera (64.2%-85.5%), indicating high taxonomic diversity at the generic level.

Table 2. Species composition of each community

Plot	Families	Genera	Species	Individuals	Monotypic families	Monotypic genera
1	40	73	154	1,421	21 (52.5%)	59 (80.8%)
2	41	83	171	1,612	22 (53.7%)	71 (85.5%)
3	50	109	271	2,112	23 (46.0%)	80 (73.4%)
4	48	94	237	1,914	20 (41.7%)	66 (70.2%)

Plot	Families	Genera	Species	Individuals	Monotypic families	Monotypic genera
5	37	69	145	1,508	17 (45.9%)	48 (69.6%)
6	38	67	126	1,421	12 (31.6%)	43 (64.2%)

Dominant families varied by plot. Plot 1 had seven families with $ $5 species, with Lauraceae (11 species), Myrtaceae (10), Euphorbiaceae (7), Leguminosae (7), and Ebenaceae (6) being most important. Plot 2 had five such families: Lauraceae (21), Rubiaceae (10), Myrtaceae (10), Theaceae (5), and Rutaceae (5). Plot 3 had 13 families with $ $5 species, led by Lauraceae (19), Euphorbiaceae (17), Myrtaceae (12), Rubiaceae (11), and Symplocaceae (11). Plot 4 had eight such families: Lauraceae (24), Myrtaceae (11), Fagaceae (10), Theaceae (10), and Rubiaceae (8). Plot 5 had five families: Lauraceae (18), Fagaceae (14), Symplocaceae (11), Theaceae (9), and Myrtaceae (8). Plot 6 had six families: Lauraceae (18), Fagaceae (13), Symplocaceae (10), Theaceae (7), and Myrtaceae (6). Lauraceae, Myrtaceae, Theaceae, Rubiaceae, and Symplocaceae were dominant across all plots, with Lauraceae being most abundant, indicating strong tropical characteristics.

2.2 Dominant Species

Dominant species play a decisive role in community structure. Survey results (Table 3) showed that Plot 1 was dominated by *Cyclobalanopsis patelliformis*, *Ixonanthes reticulata*, *Gironniera subaequalis*, *Decaspermum montanum*, and *Engelhardia roxburghiana*, with *C. patelliformis* being absolutely dominant. Plot 2 was dominated by *Schefflera heptaphylla*, *Sarcosperma laurinum*, *Ficus langkokensis*, *Meliosma angustifolia*, and *Dillenia turbinata*, with *S. heptaphylla* clearly dominant. Plot 3 had *Maclurodendron oligophlebium*, *G. subaequalis*, *D. montanum*, *F. vasculosa*, and *Psychotria asiatica* as co-dominants with similar IVs, forming a multi-dominant community. Plot 4 was co-dominated by *D. montanum*, *Dacrydium pectinatum*, *S. heptaphylla*, *Schima crenata*, and *Adinandra hainanensis*. Plot 5 was dominated by *Castanopsis chinensis*, *A. hainanensis*, *D. pectinatum*, *Machilus monticola*, and *Pentaphylax euryoides*, with *C. chinensis* absolutely dominant. Plot 6 was dominated by *Cyclobalanopsis championii*, *Diospyros howii*, *Xanthophyllum hainanense*, *D. pectinatum*, and *D. tutcheri*, with *C. championii* absolutely dominant.

Species replacement was evident with elevation. Mid-altitude communities showed transitional characteristics between lowland and montane rainforest, sharing many dominant species with both zones. *Decaspermum montanum*, *Gironniera subaequalis*, *Ficus vasculosa*, *Dillenia turbinata*, and *Sarcosperma laurinum* were shared between lowland and mid-altitude communities. *Dacrydium pectinatum*, *Adinandra hainanensis*, *Schima superba*, and *Pentaphylax euryoides* were shared between mid-altitude and montane communities. *Schefflera heptaphylla* and *Syzygium hancei* occurred across all elevations, indicating wide ecological amplitudes.

The sum of IVs for the top ten dominant species in each plot was 49.04%, 44.77%, 33.95%, 32.6%, 40.44%, and 39.88% for Plots 1–6, respectively, showing a U-shaped pattern with elevation. Mid-altitude communities had the lowest proportions and most evenly distributed IVs, characteristic of multi-dominant communities.

2.3 Species Diversity

As shown in Figure 1, Margalef richness values were 16.085, 17.073, 24.888, 23.192, 18.415, and 18.044 for Plots 1–6. Shannon-Wiener diversity values were 3.898, 3.883, 4.304, 4.471, 4.180, and 4.088. Simpson diversity values were 0.966, 0.963, 0.973, 0.982, 0.975, and 0.970. Pielou evenness values were 0.839, 0.820, 0.824, 0.883, 0.864, and 0.847. All diversity indices showed hump-shaped patterns with elevation. Montane rainforest had higher Shannon-Wiener diversity, Simpson diversity, and Pielou evenness than lowland rainforest, indicating higher species diversity and more even distribution. In lowland rainforest, Plot 1 had higher Simpson diversity and Pielou evenness than Plot 2, possibly due to more advanced successional stage and more even species distribution.

Sørensen similarity analysis (Table 4) revealed a significant negative correlation between community similarity and altitudinal difference (Pearson r = -0.66, $P < 0.01$; Spearman = -0.60, $P < 0.05$). Similarity decreased as elevational difference increased. Adjacent plots (3 vs. 4, 4 vs. 5, 5 vs. 6) had higher similarity (0.527–0.571), while distant plots (2 vs. 6, 1 vs. 6, 1 vs. 5) had lower similarity (0.218–0.252). Lowland rainforest similarity (0.349) was lower than montane rainforest (0.527). The transitional Plots 3 and 4 showed the highest similarity (0.571).

Table 4. Sørensen community similarity coefficients among plots

Plot	1	2	3	4	5	6
1	–	0.349	0.362	0.336	0.252	0.218
2	–	–	0.402	0.388	0.306	0.252
3	–	–	–	0.571	0.445	0.371
4	–	–	–	–	0.527	0.445
5	–	–	–	–	–	0.527
6	–	–	–	–	–	–

2.4 Floristic Composition

Analysis of areal types of woody plant genera (Table 5) showed that tropical distribution dominated across all elevations (82.1%–94.0%), with minimal temperate distribution and very few cosmopolitan or Chinese endemic taxa, indicating strong tropical characteristics. Tropical Asian (Indo-Malaysian) distribution was predominant (20.9%-33.9%), including *Schima*, *Machilus*, *Pentaphylax*, *Altingia*, and *Artocarpus*. Pantropic distribution was second (19.3%-25.4%), including *Schefflera*, *Cryptocarya*, *Symplocos*, and *Diospyros*. Other types included tropical Asia to tropical Australasia (11.6%-14.7%), Old World tropics (9.0%-13.8%), tropical Asia and tropical America disjunction (4.1%-9.0%), and tropical Asia to tropical Africa (2.9%-6.8%). This indicates strong tropical Asian affinity and Indo-Malaysian relationships.

Temperate distribution was dominated by East Asian and North American disjunction, including *Lithocarpus*. Mediterranean, West Asia to Central Asia distribution occurred in only one genus (*Olea*) per plot. Chinese endemic distribution was minimal, with only one genus per plot: *Semiliquidambar* in Plot 4, *Chunia* in Plot 6, and *Pyrenocarpa* in others.

Tropical distribution proportion was significantly negatively correlated with elevation (Pearson r = -0.79, P < 0.01; Spearman = -0.76, P < 0.01), while temperate distribution was significantly positively correlated (Pearson r = 0.72, P < 0.01; Spearman = 0.70, P < 0.01). Thus, tropical elements decreased while temperate elements increased with elevation.

Table 5. Areal-types of genera in each community

Areal type	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
1. Cosmopolitan	0% (0)	0% (0)	0.9% (1)	2.1% (2)	1.4% (1)	1.5% (1)
2. Pantropic	23.3% (17)	22.9% (19)	19.3% (21)	21.3% (20)	21.7% (15)	25.4% (17)
3. Trop. Asia & Trop. Amer. disjunction	4.1% (3)	8.4% (7)	6.4% (7)	7.4% (7)	8.7% (6)	9.0% (6)
4. Old World Tropics	12.3% (9)	13.3% (11)	13.8% (15)	10.6% (10)	10.1% (7)	9.0% (6)
5. Trop. Asia to Trop. Australasia	13.7% (10)	14.5% (12)	14.7% (16)	13.8% (13)	11.6% (8)	11.9% (8)
6. Trop. Asia to Trop. Africa	6.8% (5)	6.0% (5)	4.6% (5)	3.2% (3)	2.9% (2)	4.5% (3)
7. Tropical Asia (Indo-Malesia)	32.9% (24)	28.9% (24)	33.9% (37)	30.9% (29)	30.4% (21)	20.9% (14)

Areal type	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Subtotal: Tropical (2-7)	**93.2% (68)**	**94.0% (78)**	**93.6% (102)**	**89.4% (84)**	**87.0% (60)**	**82.1% (55)**
8. North temperate	0% (0)	2.4% (2)	0% (0)	0% (0)	1.4% (1)	1.5% (1)
9. E. Asia & N. Amer. disjunction	2.7% (2)	1.2% (1)	3.7% (4)	7.4% (7)	7.2% (5)	10.4% (7)
10. Mediter-ranean, W. Asia to C. Asia	1.4% (1)	1.2% (1)	0.9% (1)	1.1% (1)	1.4% (1)	1.5% (1)
11. Central Asia	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
12. East Asia	0% (0)	0.9% (1)	1.1% (1)	1.4% (1)	3.0% (2)	5.5% (4)
Subtotal: Temperate (8-12)	**4.8% (4)**	**5.5% (6)**	**5.5% (6)**	**9.6% (9)**	**11.6% (8)**	**16.4% (11)**
13. Endemic to China	1.4% (1)	1.2% (1)	0.9% (1)	1.1% (1)	1.4% (1)	1.5% (1)

2.5 Leaf Characteristics

Leaf trait analysis (Table 6) revealed that Diaoluoshan's tropical natural forests are characterized by mesophyll, simple, leathery, and entire leaves, typical of tropical regions. By leaf size, mesophyll leaves dominated (60.00%-64.56%), followed by microphyll leaves (24.56%-36.00%). Macrophyll leaves comprised 3.20%-14.04%, while leptophyll, nanophyll, and megaphyll leaves were rare. Microphyll proportion was significantly positively correlated with elevation (Pearson r = 0.63, P < 0.01; Spearman = 0.65, P < 0.01), showing a trend of decreasing mesophyll and macrophyll proportions and increasing microphyll proportion with elevation. Low-elevation plots (1 and 2) with higher temperatures and better hydrothermal conditions had larger leaf sizes, while high-elevation Plot 6 (1,130 m) with lower temperatures had smaller leaves.

By leaf type, simple leaves dominated (83.33%-95.20%) over compound leaves (4.80%-16.67%). Simple leaf proportion was significantly positively correlated with elevation (Pearson r = 0.56, P < 0.01; Spearman = 0.59, P < 0.01), showing decreasing compound leaf proportion with elevation. Lowland rainforests with better hydrothermal conditions had more large pinnate compound-leaf species.

By leaf texture, leathery leaves dominated (62.28%-75.96%) over papery leaves

(24.04%-32.46%), with few membranous leaves. Leathery leaf proportion was not significantly correlated with elevation (Pearson r = 0.16, P = 0.39; Spearman = 0.16, P = 0.40). By leaf margin, entire leaves dominated (75.32%-85.09%) over non-entire leaves (14.91%-24.68%). Non-entire leaf proportion was not significantly correlated with elevation (Pearson r = 0.11, P = 0.57; Spearman = 0.21, P = 0.26).

Table 6. Leaf characteristics of each community

Plot	Leptophyll (%)	Nanophyll (%)	Microphyll (%)	Mesophyll (%)	Macrophyll (%)	Megaphyll (%)	Simple (%)	Compound (%)	Leathery (%)	Papery (%)	Membranous (%)	Entire (%)	Non-entire (%)
1	0.00	0.00	25.96	63.46	10.58	0.00	83.33	16.67	67.76	32.24	0.00	75.32	24.68
2	0.00	0.00	24.56	60.53	14.04	0.87	84.21	15.79	62.28	32.46	5.26	78.95	21.05
3	0.00	0.00	28.65	61.08	10.27	0.00	87.70	12.30	75.96	24.04	0.00	85.09	14.91
4	0.63	0.63	27.22	64.56	6.96	0.00	89.87	10.13	73.42	26.58	0.00	82.28	17.72
5	0.79	1.59	30.16	61.11	6.35	0.00	92.06	7.94	73.02	26.98	0.00	84.13	15.87
6	0.00	0.80	36.00	60.00	3.20	0.00	95.20	4.80	74.40	25.60	0.00	80.00	20.00

Note: Le. Leptophyll; Na. Nanophyll; Mi. Microphyll; Mes. Mesophyll; Ma. Macrophyll; Meg. Megaphyll; Si. Simple; Co. Compound; 1. Leathery; 2. Papery; 3. Membranous; E. Entire; N. Non-entire.

3. Discussion and Conclusions

3.1 Species Diversity Changes

With increasing elevation, decreasing temperature, increasing humidity, and reduced human disturbance, species composition and α diversity in Diaoluoshan's tropical natural forests showed a hump-shaped "mid-elevation peak" pattern. This aligns with studies on Diaoluoshan ferns (Jiang, 2006) and Wuzhishan tropical rainforests (Zhuo et al., 2017). Lowland rainforests at lower elevations experience greater human activity, disrupting plant establishment and growth, with severe disturbance dramatically reducing diversity (Wu et al., 2021). High-elevation montane rainforests have low temperatures that affect species survival and distribution. Mid-altitude communities have optimal hydrothermal conditions and moderate disturbance that reduces competitive exclusion, maintaining high species diversity (Long, 2016; Jia et al., 2021). Additionally, Plots 3 and 4 represent the transition zone between lowland and montane rainforest with high habitat heterogeneity, further enhancing diversity (Wang & Wang, 2013). In contrast, Jianfengling in western Hainan shows an inverted S-shaped pattern (Wu et al., 2013) due to its hot, dry climate and poor soils, where low elevations support only xerophytes and mid-elevations are dominated by Dipterocarpaceae. Diaoluoshan's location in eastern Hainan provides excellent hydrothermal conditions and fertile soil, allowing diversity to increase with decreasing disturbance at mid-elevations, reflecting plant adaptation to habitat conditions.

Different species have different ecological amplitudes, and dominant species showed clear replacement with elevation. Sørensen similarity decreased with increasing elevational difference. Significant differences in geomorphology and hydrothermal conditions between lowland and montane rainforests created distinct species distribution patterns. Lowland rainforests had low similarity and abundant monotypic families and genera (Wang et al., 2015), possibly because 1950s logging (Li, 1995) and frequent disturbance allowed new species to colonize the fertile soils, forming mixed lowland rainforest rather than Dipterocarpaceae-dominated forest (Huang et al., 2013). Montane rainforests showed high similarity with *Dacrydium pectinatum* as a shared dominant, indicating good protection and late successional stages.

3.2 Floristic Composition Changes

Floristic composition was overwhelmingly dominated by tropical elements, primarily tropical Asian (Indo-Malaysian) distribution, indicating strong tropical Asian affinity. Temperate elements were dominated by East Asian and North American disjunction, differing from Bawangling' s montane rainforest where Fagaceae dominance shows more North temperate distribution (Lü, 2012), reflecting regional differences in species origin and migration history. With increasing elevation and decreasing temperature, floristic composition shifted from tropical to temperate elements (Su, 2007; Zhu, 2008; Wu et al., 2021), consistent with latitudinal patterns (Wu et al., 2006).

Excessive human disturbance reduces narrow-range and characteristic species while increasing invasives and widespread species (Cheng et al., 2014), simplifying floristic composition. Complex, special habitats favor the survival of endemic, rare, and ancient relict species (Wei et al., 2009). Generally, Chinese endemic distribution increases with elevation as disturbance decreases (Su, 2007), making floristic composition more complex (Wu et al., 2021). However, Diaoluoshan had few Chinese endemic genera at all elevations, indicating weak endemism, likely due to 1950s logging (Li, 1995) that eliminated narrow-niche endemics.

3.3 Leaf Characteristics Changes

Leaf traits reflect long-term plant adaptation to habitats and indicate environmental conditions. With decreasing latitude and increasing temperature and humidity, deciduous species decrease while evergreen species increase, and leaf traits show decreasing proportions of microphyll, compound, herbaceous, and non-entire leaves and increasing proportions of mesophyll, simple, leathery, and entire leaves (Kong et al., 2009). Diaoluoshan' s excellent hydrothermal conditions produce the typical tropical appearance of mesophyll, simple, leathery, and entire leaves (Wang, 1987). Dense tropical forest canopies shade sunlight and partially block rainfall, and larger leaves help capture light and evaporate water to cool leaves. Leathery leaves reflect intense sunlight and reduce transpiration (Su, 2007), adapting to tropical heat.

Compared with Bawangling’ s Fagaceae-dominated montane rainforest (Lü, 2012), Diaoluoshan had smaller leaf sizes and lower proportions of compound and papery leaves, related to Bawangling’ s valley location with hot, humid climate favoring megaphyll species, and its inclusion of herbs and ferns increasing compound and papery leaf proportions. Leaf size decreases from warm-humid to dry-cold areas (Wang, 1987). With increasing elevation, temperature decreases and humidity increases, and leaf size changes resemble latitudinal patterns (Liu et al., 2013), while leaf type changes show the opposite trend. Lowland rainforests in valleys have warm, humid equatorial-like climates with many large pinnate-compound species, while high elevations have strong winds and low temperatures that reduce leaf area. Thus, leaf traits reflect plant adaptation to habitats under combined influences of hydrothermal conditions, light, and historical origin.

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