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Diversity and distribution of ground bryophytes in broadleaved forests in Mabian Dafengding National Nature Reserve, Sichuan, China

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ABSTRACT

Bryophytes, represented by mosses, liverworts, and hornworts, contribute substantially to forest ecosystems in terms of nutrient cycling, water retention, water availability, plant biomass, and plant community maintenance. Forests provide numerous types of habitat for bryophytes, especially the ground floor. To clarify the ground bryophyte diversity and distribution in broadleaved forests, we used microcoenose sampling to investigate ground bryophytes in 34 sample plots (10 × 10 m) in the Mabian Dafengding National Nature Reserve (MDNR), Sichuan Province. Species diversity and environmental factor relationships were analyzed by using α and β diversity indexes, as well as Pearson's correlation analysis. Detrended canonical correspondence analysis (DCCA) was applied to analyze the relationships between species distribution and environmental factors. A total of 230 bryophyte species were identified in MDNR. These species include 67 liverwort species belonging to 26 genera of 20 families and 163 moss species belonging to 65 genera of 28 families. Diversity of ground bryophytes was negatively correlated to shrub cover, canopy cover, and tree number, but without significant correlations to altitude, slope, aspect, vegetation type, and herb cover. The DCCA ordination of relationships between ground bryophytes and environmental factors showed that altitude, aspect, vegetation type, and shrub cover were important to the distribution of dominant ground bryophyte species. This study quantitatively related bryophytes diversity and distribution to environmental factors, which is helpful in understanding the ecological niche of various bryophytes.

1. Introduction

Bryophytes, with a variety of ecological communities, are widely distributed globally. Ground bryophytes are those that grow in the substrate of floor soil. Ground bryophytes form a dominant ecological group in the forest ecosystems and also serve an important function in forest ecosystems in such processes as the carbon and nitrogen cycles [1–3]. For example, in a boreal forest, ground bryophytes serve as the primary carbon sink over woods and are main contributors to carbon equilibrium [3,4].

Broadleaved forest is a typical and widely distributed vegetation type in China that provides various suitable environments and substrates for bryophytes. Thus, the distribution of ground bryophytes in the forest is influenced by forest cover (light intensity), stands, composition, and structure [5–9]. Human activities, such as deforestation and reforestation, have changed the forest, consequently influencing the diversity, abundance, and distribution of ground bryophytes [10,11]. Additionally, macroclimatic factors such as rainfall and temperature, site factors such as topography and understory vascular, as well as substrate characteristics such as soil moisture and pH probably induce certain effects [7–9,12–15]. Nature reserve, especially with humid environment, is an important area of biodiversity conservation and is a vital ecological region that preserves a large amount of ground bryophytes. The habitat heterogeneity of ground bryophytes is relatively high in broadleaved forests [6,8]. Thus, ground bryophyte diversity and distribution must be clarified to aid in the conservation of bryophytes and their habitat. In this study, we illustrate the relationships of the diversity and distribution of bryophytes with environmental factors by analyzing ground bryophytes of different environment regimes through correlation and ordination analyses.

2. Methods

2.1. Study area

This study was conducted in the Mabian Dafengding National Nature Reserve (MDNR) (28°26′–28°47′N, 103°13′–103°25′E). MDNR is located in the southwest of Mabian Yi Autonomous County,

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Sichuan Province and covers an area of 36 000 hm^2, with altitude ranging from 800 m to 4042 m a.s.l. The altitude difference of more than 3000 m causes the temperatures to be significantly distinct in this region. At 1500 m a.s.l., the annual mean temperature is 14–15 °C, with 3–4 °C in the coldest month of January and 22–24 °C in the hottest month of July. In areas above 3800 m a.s.l. (close to the summit of MDNR), the annual mean temperature is −2 °C to 0 °C, and the minimum extreme temperature is lower than −30 °C. Summer does not occur throughout the year, spring and autumn are short (approximately 60 d), and winter is long (approximately 300 d), thus resulting in a cold temperate climate. The annual precipitation in the study area is 1739.2 mm, reaching the maximum (more than 2000 mm) between 2000 and 2100 m a.s.l. Similar to climate, soil types and vegetation are vertically distributed from the bottom to the top. Below 2200 m a.s.l., the soil type is mountainous yellow soil and dominated by tropical evergreen broadleaved forest. Between 1800 and 2400 m a.s.l., the soil type is mountainous yellow brown soil and dominated by evergreen and deciduous broadleaved mixed forest. Between 2400 and 2800 m a.s.l., the soil type is mountainous dark brown soil, and corresponding vegetation is coniferous and broadleaved mixed forest. Between 2800 and 3500 m a.s.l., the soil type is mountainous dark brown coniferous forest soil, vegetated by dark coniferous fir forest. Above 3500 m a.s.l., the soil type is mountain meadow soil, vegetated by subalpine shrub and meadow [16].

2.2. Field sampling

For different broadleaved forest types, several sample sites were surveyed along an altitude gradient from 1300 m to 2300 m in MDNR. Within each site, the community features of trees, shrubs, and herbs, were measured in a 10 × 10 m sample plot. These features included cover, height, and abundance. Thirty-four sample plots were investigated. At the four corners of each sample plot, shrubs and herbs were investigated in quadrates of 3 × 3 m and 1 × 1 m individually. The covers of canopies, shrubs, and herbs were measured by visual estimation, as well as tree height. Other vascular community features, including height and abundance, were recorded by measuring and counting. For ground bryophytes, microcoenose sampling method [17] was employed (sampling with the 50 × 50 cm quadrate at the center of the largest fragment in each of 25 2 × 2 m grids) to measure species cover. Unequal quadrates (2–25) were sampled in the 34 plots. We also recorded the geographic locations and topographic factors of the plots. These parameters include longitude, latitude, altitude, slope, and aspect. Soil pH and moisture were not measured in this study for two reasons. First, previous studies showed that soil pH does not influence the bryophytes diversity and growth of the same vegetation type in one certain region [7]. Second, rainfall is adequate in the study area, and the understory is rather humid. Table 1 shows the detailed environmental information of each sample plot. We collected all bryophyte specimens and identified them according to the literature in the laboratory. Some suspected specimens were identified by native bryologists. All the specimens were stored in BAU.

2.3. Data analysis

$$\text{Frequency} = (\text{quadrates of bryophytes presence}/\text{total investigated quadrates})/100\%$$

$$\text{Importance value} = (\text{relative cover} + \text{relative frequency})/2$$

We defined dominant family as a family of five or more bryophyte species and dominant species as species with an importance

Table 1
Summary of sample plots in MDNR.

Sample plot	Longitude	Latitude	Altitude	Canopy cover	Shrub cover	Herb cover	Slope	Aspect	Number of trees
M1	103.3295	28.4924	1553	0.80	0.05	0.92	30	350	3
M2	103.3300	28.4925	1516	0.80	0.10	0.50	40	250	5
M3	103.3314	28.4954	1518	0.40	0.12	0.60	45	295	3
M4	103.3326	28.4958	1554	0.70	0.15	0.64	30	20	4
M5	103.3372	28.4985	1523	0.50	0.45	0.55	25	295	5
M6	103.3370	28.4990	1524	0.70	0.10	1	17	345	4
M7	103.3419	28.5011	1436	0.85	0.20	0.83	35	20	5
M8	103.3410	28.5020	1462	0.80	0.15	0.20	33	30	4
M9	103.3481	28.5745	1434	0.65	0.13	0.45	30	82	4
M10	103.3475	28.5749	1424	0.35	0.12	0.74	28	18	2
M11	103.3460	28.5751	1495	0.60	0.25	0.25	20	270	5
M12	103.3529	28.5755	1339	0.40	0.06	0.70	35	188	2
M13	103.3506	28.5757	1358	0.60	0.100	0.50	32	192	3
M14	103.3495	28.5782	1549	0.55	0.19	0.61	40	250	4
M15	103.3483	28.5790	1464	0.78	0.1	0.28	20	205	2
M16	103.3473	28.5794	1409	0.75	0.14	0.45	28	280	4
M17	103.3462	28.5820	1375	0.30	0.09	0.72	5	252	2
M18	103.3447	28.5841	1464	0.40	0.07	0.50	40	70	4
M19	103.3431	28.5848	1464	0.64	0.14	0.78	45	30	4
M20	103.3387	28.5877	1489	0.42	0.08	0.81	34	180	4
M21	103.3379	28.5914	1619	0.30	0.03	0.71	5	70	2
M22	103.3364	28.5938	1696	0.45	0.18	0.60	35	210	3
M23	103.3783	28.6827	1794	0.60	0.85	0.02	40	165	3
M24	103.3760	28.6831	1924	0.30	0.65	0.38	25	170	1
M25	103.3640	28.6846	1812	0.70	0.16	0.48	5	168	1
M26	103.3684	28.6852	1921	0.12	0.04	0.65	25	110	1
M27	103.3682	28.6859	1951	0.60	0.55	0.30	27.5	195	3
M28	103.3675	28.6884	1979	0.20	0.38	0.47	27	150	1
M29	103.3584	28.6887	2110	0.30	0.95	0.01	45	200	1
M30	103.3598	28.6904	2203	0.80	0.85	0.27	32	246	1
M31	103.3615	28.6915	2113	0.60	0.12	0.70	32	264	2
M32	103.3595	28.6920	2221	0.80	0.90	0.01	45	80	4
M33	103.363	28.6926	2040	0.30	0.60	0.27	20	210	1
M34	103.365	28.6927	2034	0.40	0.01	0.48	22	187	3